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The Honorable Thomas O. Rice

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF WASHINGTON

AJ AND JODI OCHOA, individually and the marital community composed thereof; TERRA GOLD FARMS, INC., a Washington corporation; A&C LAND COMPANY, LLC, a Washington limited liability company; and AJ OCHOA CORPORATION, a Washington corporation, Plaintiffs, v. INDUSTRIAL VENTILATION, INC., an Idaho corporation; and TETON WEST OF WASHINGTON, LLC, an Idaho limited liability company, Defendants.	NO. 2:18-cv-00393-TOR **DECLARATION OF ROBERT BOMBINO IN OPPOSITION TO IVI'S MOTION FOR SUMMARY JUDGMENT**

Robert Bombino declares as follows:

1. I am over 18 years of age and competent to testify as a witness in this action. I make these statements of my own personal knowledge. I am the President and Senior Building Science Specialist at RDH Building Science. I hold a Bachelor of Applied Science degree in Civil Engineering from the University of Waterloo,

BYRNES • KELLER • CROMWELL LLP
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Ontario, Canada, and a Master of Science degree in Architectural Engineering from Pennsylvania State University. I have extensive experience and specialize in evaluating the design and performance of building enclosure systems, including evaluating thermal and hygrothermal (heat, air, and moisture) performance of building enclosure systems. Together with my colleague Chris Schumacher, I prepared an expert opinion and report in this matter regarding the performance of the vegetable storage facilities at issue in this matter.

2. Attached hereto as Exhibit 1 is the Expert Opinion and Report of RDH Building Science prepared by me and my colleague, Chris Schumacher, in this matter ("RDH Report").

3. A short biography describing my education, training, experience, and qualifications is attached as Exhibit A to the RDH Report.

4. A short biography describing Chris Schumacher's education, training, experience, and qualifications is also included in Exhibit A to the RDH Report.

5. If called to testify at trial, I would testify to the opinions set forth in the RDH Report regarding the performance of, and significant problems with, the vegetable storage equipment, systems, and facilities at issue in this case.

I certify under penalty of perjury that the above is true and correct to the best of my knowledge.

DATED this 11th day of May, 2020 in Seattle, Washington.

By ______________________
Robert Bombino

CERTIFICATE OF SERVICE

I hereby certify that on this 12th day of May, 2020, I electronically filed the foregoing with the Clerk of the Court using the CM/ECF System, which in turn automatically generated a Notice of Electronic Filing (NEF) to all parties in the case who are registered users of the CM/ECF system. The NEF for the foregoing specifically identifies recipients of electronic notice.

By /s/ Jofrey M. McWilliam
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EXHIBIT A

RDH BUILDING SCIENCE

Othello Storage – RDH Investigation and Opinion Report

Project 21641.000

Terra Gold Farms, 850 N. Broadway Avenue, Othello, WA

To: Mr. Jofrey McWilliam
Byrnes Keller Cromwell LLP
1000 Second Avenue, 38th Floor
Seattle, WA 98104

Submitted: Nov 18, 2019 by
RDH Building Science Inc.
2101 N 34th St #150,
Seattle, WA 98103

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1 Introduction

1.1 Terms of Reference

RDH Building Science Inc. (RDH) was engaged by Byrnes Keller Cromwell LLP (BKC) to provide professional consulting services for its client, Terra Gold Farms (TGF). Specifically, BKC asked RDH to investigate the circumstances that resulted in the failure of the stored potato and onion crop in several bays at TGF's Othello storage facility during the 2015 and 2016 storage seasons. TGF's Othello storage facility comprises two storage systems, the first completed in 2012, and the second in 2015, both designed and constructed by Industrial Ventilation Inc. and Teton West (collectively referred to as IVI). RDH was asked to evaluate the HVAC systems at the Othello storage facility and to assess whether these systems and IVI's role in their design, construction and commissioning contributed to the failure of the stored crops.

1.2 Work Completed for this Report

RDH's scope of work included the following:

- → Review current facility including bays in original configuration and modified bays.
- → Review the history of reported problems and system modification made to solve these as provided by AJ Ochoa of TGF and Jerry Laramore.
- → Review industry guidance for potato and onion storage.
- → Review and evaluate relevant project documents including Industrial Ventilation Inc. (IVI) marketing brochures, contracts, and construction documents, and email correspondence between IVI, and TGF and their Counsel.
- → Conduct testing to characterize and quantify key HVAC system performance parameters.

Key objectives for this work were:

- → Provide an opinion whether the design and implementation of the original systems contributed to the failure of the stored crops.
- → Provide an opinion whether failure to properly commission, troubleshoot, and service the original systems contributed to the failure of the stored crops.

1.3 RDH Building Science

RDH Building Science Inc. was founded in 1997 in Vancouver, BC, originally as RDH Building Engineering Ltd. In 2004, RDH opened offices in Seattle, WA and Portland, OR, originally as RDH Building Sciences Inc. Currently, RDH operates 9 offices, spread across North America, and employees approximately 270 staff comprised of Engineers, Architects, Scientists, Technologists. and Construction Managers. RDH provides professional consulting services to a wide range of clients in the areas of Building Science, Building Enclosures, Energy and Sustainability, Research, Forensic Engineering, and Construction Project Management. Typical projects include new construction, existing building assessment and renovation, forensic work in support of dispute resolution or litigation support, as well as building science research, training, and publications for the construction industry at large.

1.4 Investigation, Authorship and Review

C. J. Schumacher, M.A.Sc.(BldgSci), B.A.Sc. (CivEng), B.Tech. (ArchSci), is a Principal and Senior Building Science Specialist. He holds a Bachelor of Technology in Architectural Science, a Bachelor of Applied Science in Civil Engineering, and a Master of Applied Science in Civil Engineering (Building Science focus). Mr. Schumacher specializes in the design of climate-control systems for specialist applications, and the investigation of building enclosure and climate-system control problems. Refer to Appendix A for a copy of Chris' Staff Biography.

Mr. Schumacher acted as senior investigator, and primary author of this report.

Robert Bombino, M.S. P.E. (WA, MA), is President of RDH and a Senior Building Science Specialist. He holds a Bachelor of Applied Science degree in Civil Engineering and a Master of Science degree in Architectural Engineering. Mr. Bombino specializes in evaluating the design and performance of building enclosure systems. Refer to Appendix A for a copy of Robert's Staff Biography.

Mr. Bombino provided Senior technical oversight and review of the work contained herein.

Please refer to Appendix B for a copy of RDH's Rate Sheet.

2 Claim

RDH's understanding of the claim and its background are based on a review of the Complaint and Jury Demand (No. 2:18-CV-393)-1 as prepared by BKC and supplemented through our own internet research and conversations with TGF's owners, A J and Jodi Ochoa.

2.1 Background

Terra Gold Farms is owned and led by AJ and Jodi Ochoa. AJ and Jodi are the fourth generation of the Ochoa family to farm in Othello, WA. The Ochoas grow, harvest, and bring to market several crops, including potatoes and onions, that are stored for extended periods of time after harvest and before they are brought to market.

In April of 2012, TGF engaged in a contract with IVI to have the first of two controlled-climate potato/onion storage facilities constructed at 300 North Lee Road, Othello, WA. This facility, located at the south end of the property and referred to as "Green Point 1" or "GP1", measures approximately 425 ft. x 270 ft. and comprises 4 independently conditioned and controlled storage bays, each measuring approximately 384 ft. in length x 62 ft. in width. Each bay is served by its own HVAC (mechanical) system. The mechanical systems and bays are grouped in pairs with each pair served by a fan house located at the east end of the structure. Each storage bay is designed to store 9000 lbs of potatoes (to a depth of 18 ft.) or 4000 lbs of onions (to a depth of 10 ft.)

In December of 2014, TGF contracted IVI to construct the second controlled-climate potato/onion storage facility, "Green Point 2" or "GP2". GP2 is the same size and geometry as GP1. Each storage bay is designed to store 9000 Tons of potatoes (to a depth of 18 ft.) or 5200 Tons of onions (to a depth of 12 ft.) The major differences between the bays of GP2 and those of GP1 are:

→ The bays in GP2 employ 5 axial fans rather than 4 as were used in GP1. RDH understands the additional fans were added to help meet the higher airflow rates required for the storage of onions.

→ The bays in GP2 are fitted with heating systems at the return/fresh air mixing chamber. These facilitate the curing process of onions.

Terra Gold Farms reports experiencing significant equipment breakdowns and malfunctions in both the GP1 and GP2 storage facilities. TGF experienced heavy loss of stored potato and onion crops in 2015 and 2016. TGF owns and operates other storage facilities but have only experienced such heavy crop losses in the storage systems that were designed, manufactured, and installed by IVI.

2.3 Causes of Action

Complaint and Jury Demand (No. 2:18-CV-393)-1 includes the following (the numbering below corresponds to the article numbers listed in the Complaint; not all articles are reproduced here):

17. A vegetable storage facility consists of a structure and component parts and equipment that function together as a single system that, among other things, regulates, alters, adjusts, monitors and controls the storage conditions of the facility/system.

33. The storage facilities designed, constructed, installed, monitored and serviced by IVI have significant defects in design, manufacture, construction, installation, assembly, equipment selection, equipment location, and/or system controls. These problems have resulted in chronic equipment failure and the failure and breakdown of the systems as a whole, resulting in millions of dollars in lost crops, among other damages.

35. IVI breached duties owed to the Ochoas because the facilities were negligently designed, manufactured, constructed, assembled, installed, monitored, and/or serviced.

36. The control panels were negligently designed and installed and failed to properly monitor and control conditions in the storage facilities.

38. The storage systems were not properly completed, tested, and inspected prior to use, and subsequent repairs and inspections were negligently done.

40. The defects in the storage system have resulted in critical and chronic equipment breakdowns, and the failure/breakdown of the system as a whole.

43. IVI was negligent in the design, manufacture, construction, assembly, selection, and installation of the storage facilities, and each of their component parts.

50. IVI failed to warn of potential issues and problems with the facilities, failed to warn of any supposed “break in” period, and otherwise failed to provide information and warnings that it was duty-bound to provide to the Ochoas. Had such warnings or instructions been provided, some or all of the losses would have been averted.

53. IVI specifically claimed that its storage systems were state-of-the art, that it was an industry leader in providing such systems, that there was no better facility for vegetable crop storage, and that IVI’s monitoring and other services were the best in the potato and onion storage industry.

73. Industrial Ventilation and Teton West each breached their obligations under their respective contracts with the Ochoas by failing to deliver completed, properly-functioning storage systems, and by failing to provide four independent storage zones in each facility.

3 Document Review

RDH were provided several hundred documents relating to the storage facilities and to potato and onion storage parameters and procedures. Several documents were identified and reviewed as they were deemed to be most relevant to RDH's scope of work. RDH was able to identify further open-source industry guidance. Appendix C provides a list of the documents reviewed as part of RDH's investigation.

The following summary addresses key observations from RDH's review of open-source industry and project-related documentation.

3.1 Industry Consensus Standards

The industry recognizes three storage periods for potatoes: The "suberization" or wound healing and curing period, the "holding" or storage period and finally, the "removal" period. Different airflow rates, and temperature and relative humidity conditions are recommended for each of the three storage periods.

Similar periods are recognized for onions: drying, curing, cooling, holding/storage and conditioning before market. However, onion storage requires different airflow rates, and temperature and relative humidity conditions than potato storage.

Stored fresh vegetables respire, producing heat, consuming oxygen, and giving off carbon dioxide. The storage environment must be properly ventilated (by controlled exchange of fresh and stale air) to control oxygen and carbon dioxide levels, and to assist in the control of temperature. The temperature of the storage environment must be managed to control the conversion of starch to sugar and sugar to starch (to suit the end use), and to inhibit/control sprouting. Relative humidity must be managed to control moisture loss (shrinkage) while preventing condensation (which could promote rot/decay).

The following sub-sections summarize industry guidance for airflow rates, and storage temperature and relative humidity levels for the storage of potatoes and onions.

3.1.1 Potatoes

1985, Pacific Northwest Cooperative Extension, bulletin PNW 257 "Potatoes – Storage and Quality Maintenance in the Pacific Northwest

→ "For proper healing and maturation of tubers, maintain relative humidity level of at least 95% in the ventilating air plus a temperature of 45° to 55°F. A temperature of 50°F is ideal for wound healing, while at the same time minimizing rot infection."

→ Seed Potatoes: "The ideal temperature for storing seed potatoes is 38° to 40°F for most varieties."

→ Fresh Market Potatoes: "tubers destined for French frying or dehydration [should be stored] at 45° to 47°F. If stored at temperatures below 45°F, tubers accumulate sugars, which result in dark fry color"

→ Chips: "keep potatoes for chipping at 50°F to prevent starch to sugar conversion. Excellent color potato chips can be made from Norchip and Kennebec tubers stored at

consistent temperatures of 45° and 47°F, depending on cultural and storage management practices."

- → "Relative Humidity (RH) for the ventilating air should be a minimum of 95%."
- → "High humidity air (100% RH) will not cause condensation or wet tubers if the ventilating air is cooler than the tubers in the pile, and if the storage is properly insulated."
- → "Use a ventilation rate which will maintain a desired temperature throughout the pile of potato tubers. Generally, tubers will be slightly warmer at the top of the pile than at the bottom."
- → "Ventilation rate should be 0.5 to 1.0 cubic feet of air per minute per 100 pounds of potatoes (cfm/cwt), depending upon availability of cool air." RDH notes that this works out to 10 to 20 cfm/Ton of potatoes. Older documentation tended to guide operators to lower airflows, while more recent documents require comparatively higher airflows.
- → "During the holding period, as little as 0.25 cfm/cwt will maintain uniform temperature through the pile, even when used on an intermittent (discontinuous) basis."
- → "Locate the return air duct at the peak or highest point of the storage structure to exhaust warm air from the storage, or to cool, humidify, and redistribute it back beneath the pile of potatoes."
- → "Use adequate insulation to keep a minimum temperature differential between the ceiling and the inside air."

1993 (reprint), Washington State University Cooperative Extension, bulletin EM2799, "Potato Storage and Ventilation"

- → "In the wound healing and curing period, immediately after being placed in storage, potatoes need a temperature of about 50°F. and a relative humidity of 90% to heal the wounds caused by harvesting and handling. After maintaining this temperature for two to three weeks, potatoes should be further cooled to the storage temperature."
- → "Conditions for the holding or storage period are a temperature of 45 to 48°F with 90% relative humidity. If sprout inhibitors have been used, the storage temperature may be as high as 48° but, without sprout inhibitors, a temperature of 40 to 42°F is necessary to prevent sprouting."
- → "the storage temperature is a compromise between the temperature which will best reduce the conversion of starch to sugar"
- → "Temperatures near 32°F. would best keep potatoes from sprouting; however, very little sprouting will occur at 40°F. If sprout inhibitors are used, very little sprouting will take place during a normal storage period if the temperature is held at 48°F."
- → "In the removal period cold brittle potatoes are easily injured. Therefore it is advisable to warm the tubers to a temperature of 50 or 60°F before removing them from storage."

→ "There are two functions of insulation in a potato storage. First is the usual function of maintaining proper temperature, and second is to prevent condensation on the inside surfaces."

→ "With high relative humidities the dew point is nearly as high as the ambient temperature. Thus, a surface only slightly cooler than the surrounding air will cause condensation."

→ "The maximum amount of air is required for the wound healing and curing period." "A minimum of 17 cubic feet per minute per ton of potatoes is required during this period."

→ "After the potatoes have been cooled to storage temperature, and after the outside air temperatures are somewhat lower than during harvest, a smaller amount of air, about 7 or 8 cubic feet per minute per ton on an intermittent basis, will maintain storage temperature."

→ "A relative humidity of 90 per cent is desirable during all of the storage periods and especially during the wound healing and curing period."

→ "A humidifier with a capacity of about 1 gph/1,000 cfm of air is needed."

→ "In years when temperature is higher than normal, night cooling plus all available evaporative cooling is likely to be less than needed to cool the potatoes to 50°F in the first 24 hours. It is these years that make refrigeration attractive for cooling. Refrigeration may also prove beneficial to lengthen the storage season the following spring and summer."

2011, Belyea, Maine Dept of Agriculture, Food, and Rural Resources, "Engineering Winter Storage Facilities for Vegetable Crops"

→ Potatoes, bulk density: 40 pcf

→ Storage Temperature: 38-45°F

→ Humidity: 95-100%

→ Airflow: 1.0-1.5 cfm/cwt → 20-30 CFM/Ton (where cwt = 100 lb. and Ton = 2000 lb.)

→ Heat of Respiration: 800-2000 Btu/Ton/day

→ Storage time: 12 months

2012 Olsen and Cunnington – World Potato Congress Workshop 1: "Storing Potatoes Perfectly"

→ The authors compare trends in North American and European potato storage

→ Storage temperatures
North America: 3-7°C (37.4-44.6°F) for fresh; 7-12°C (44.6-53.6°F) for processing

→ Conditions/locations dictate airflow
North America = maximum 25 cfm/ton
Europe = higher airflows: 75 cfm/ton

2017 (May), Canadian Horticultural Council
"Control of Potato Storage Conditions for the Management of Post-harvest Losses due to Diseases"

→ "At temperatures below 4.0°C most potato varieties will remain dormant during a normal storage season (up to 8 months). At temperatures above 4.0°C the dormant period decreases as the temperature increases." (4°C = 39.2°F)

→ "Maintaining uniform temperatures is critical as fluctuations shorten dormancy."

→ "Temperature has an important relationship with relative humidity (RH). Warm air holds more moisture than cold air. Thus, even small changes in temperature can cause dramatic changes in relative humidity."

→ To avoid fluctuations in RH, which stress the tubers and can lead to condensation problems, maintaining a uniform temperature is essential."

→ The majority of storage diseases are partially or completely inhibited by storage temperatures below 7.2°C" (7.2°C = 45°F)

→ "Curing can begin soon after the storage is full. Cool, or warm, the pile to 13.0-15.5°C and maintain for 10-14 days along with a humidity of 92-97% RH"
(13.0-15.5°C = 55.4-55.9°F)

→ Seed: "Cool gradually at the rate of 1.0°C every 1-2 days to a holding temperature of 3.0-4.0°C." (1°C = 1.8°F; 3-4°C = 37.4-39.2°F)

→ Table Stock: "Cool at a rate of 1.0°C every 3-4 days to a holding temperature of 4.5 to 5.5°C." (4.5 to 5.5°C = 40.1 to 41.9°F)

→ Processing Stock: "Cooled slowly at approximately 1.0°C per week. Rapid cooling tends to cause sugar accumulation. Secondly, for short to intermediate holding of processing potatoes, the holding temperature should not be below 7.2°C (45°F) unless the variety is known to store well at lower temperatures. Potatoes to be processed into French fries before Christmas can be held at 10.0°C (50°F). Chip stock can be held at slightly higher temperatures, 10.0-12.0°C (50-53.6°F). For storage after Christmas, and up until the early part of May, both chip and French fry stock can be held at 8.0-10.0°C (46.4-50°F)."

→ "Ventilation systems capable of blending outside air with inside air should be designed to move air at a rate of no less than 1.0 cfm/cwt (20 cfm/ton) of potatoes stored."

→ "In general, a RH of 92-97% for dry, healthy potatoes and 85-90% for wet, leaky potatoes is recommended."

3.1.2 Onions

1985, Pacific Northwest Cooperative Extension, bulletin PNW 277, "Onion Storage Guidelines for Commercial Growers"

→ Drying: "If external free moisture is present on onions when you bring them into storage, remove it as quickly as possible… …dry them in bulk storages by forcing 2 cubic feet of air per minute per cubic foot of onions (2 cfm/ft3) through the pile. Start air flow as soon as onions cover the first air duct." RDH estimates that an airflow rate of 2 cfm/cu ft is equivalent to approximately 87 cfm/Ton of onions (assuming onions have a bulk density of about 46 pcf).

→ "To preserve onion quality, air supplied to the storage should not have a relative humidity higher than 75%"

→ "When you use heated air, keep its temperature below 95°F (35°C)"

→ Curing: "ventilation up to 2 cubic feet of air per minute for each cubic foot of onions (2 cfm/ft3)"; "temperature up to 95°F (35°C)"; "air moisture content – less than 50% relative humidity"

→ Cooling: "After drying and curing, lower the temperature of stored onions steadily and evenly to the desired storage temperature."

→ "If onions are colder than the dewpoint temperature of the ventilating air, condensation will occur."

→ "Large variations of temperature within the onion pile can lead to dehydration of those onions nearest the ventilating tubes and to condensation problems on the surface of the cooler onions."

→ When you use refrigeration, lower the temperature of the onion storage air slowly to 33°F (0.5°C)."

→ Holding: "The best holding temperature for onions is at or near 33°F (0.5°C), with a relative humidity between 60 and 70%"

→ Conditioning: "You will often need to condition your onions before you package them either by holding them in a warm packing plant or by conditioning them before you move them into a packing line. During this time, there is danger of water condensing on the onions if the air has a high moisture content." "Air at a temperature of 68˚F (20°C), with a relative humidity of 50%, has a dewpoint near 50°F (10°C). If onions at 40°F (4.4°C) are exposed to this air, moisture will condense on the surface of the onions."

1992, Boyette et al. North Carolina State,
"Postharvest Cooling and Handling of Onions"

→ Drying Conditions: Temperature 100°F; Relative Humidity: 65%

→ Storage Conditions: Temperature 32°F; Relative Humidity: 70%

→ Freezing Temperature: 31°F

→ Airflow rate of "3 to 5 cubic feet per minute per bushel of onions." RDH estimates that these flow rates are equivalent to approximately 100-180 cfm/ton (assuming onions have a bulk density of 46 pcf and given a bushel is 1.25 cu ft.

2011, Belyea, Maine Dept of Agriculture, Food, and Rural Resources,
"Engineering Winter Storage Facilities for Vegetable Crops"

→ Onions, bulk density: 46 pcf

→ Storage Temperature: 32-45°F

→ Humidity: 70-75%

→ Airflow: 2.0-2.5 cfm/cwt → 40-50 CFM/Ton

→ Heat of Respiration: 900-2500 Btu/Ton/day

→ Storage time: 1-8 months

3.2 Proposals and Contracts

IVI's proposal and contract for the first storage system, Greenpoint 1, indicates that the design is based on storage of 36,000 Tons of potatoes in four "Independent Zones" or storage bays (9000 Tons of potatoes per bay). The proposed design for GP1 employs four axial fans per bay, installed in parallel.

The proposal and contract for the second storage system, Greenpoint 2, indicates the same design basis: 36,000 Tons of potatoes across four storage bays. The second proposal also includes an additional "Onion Storage Evaluation" where IVI considers storage of 10, 11, and 12 ft. pile heights of onions. This corresponds to a design basis of 8600, 9600, and 10,400 Tons of onions per pair of storage bays (4300, 4800, and 5200 Tons of onions per bay). The proposed design for GP2 employs five fans per bay.

3.2.1 Potatoes

March 30, 2012 – IVI Proposal for first storage system:
"Terra Gold Two 18,000 ton Potato Storages"

→ Each storage bay in the Greenpoint 1 employs four axial fans installed in parallel.

→ "Fan, 54", 25 HP, 1150 RPM, 3 Phase, 6-9WR"

→ Total airflows for one pair of storage bays (2 storage bays x 4 fans = total of 8 fans):

  - → "Available system operation": 464,000 cfm @ 1.25" SP (inches static pressure) for 25.7 CFM/Ton of potatoes.
  - → "Normal system operation" is indicated at 378,000 cfm @ 1.25" SP for 21 CFM/Ton of potatoes
- → "Ceiling insulated with a drop ceiling, with 1 in. foil board, vapor barrier and Insulsafe blow in fiberglass insulation with R-40 total rating."
- → "15 powered ridge ventilators to provide air exchange in ceiling cavity"
- → "Refrigeration ratio: one ton of refrigeration per 84.5 tons of potatoes"

April 20, 2012 – IVI "Contract AAAQ2175"

- → IVI's contract for the first storage system, GP1, shows a date of April 20, 2012 on the first page but a date of April 6, 2012 on the signature line.
- → The specifications section in the top right of the first page indicates the total flow rate for all four storage bays (i.e. 16 fans), is:
  - → 756,000 "Total CFM"
  - → works out to a design flow rate of 47,250 cfm per fan or 189,000 cfm per bay
  - → Crop listed as stored "Potato"
  - → Total weight of stored product (i.e. for 4 bays) as 36,000 tons or 9,000 tons per bay.
  - → The design flow rate per ton of potato stored then works out to 21 cfm/ton.

3.2.2 Onions

December 11, 2014 – IVI Proposal for second storage system: "Terra Gold Farms 36,000 Ton Potato Storage"

- → Each storage bay in Greenpoint 2 employs five axial fans, again installed in parallel.
- → "Fan, 54", 25 HP, 1150 RPM, 3 Phase, 6-9WR" (the same fans as GP1)
- → Total airflows for one pair of storage bays (compares 4 and 5 fan designs for onion storage)
  - → Using the "current" system (i.e. 2 bays x 4 fans = 8 fans): 464,000 cfm "Storage capacity at 10' pile height": 8600 Ton = 54 CFM/Ton
"Storage capacity at 11' pile height": 9600 Ton = 48 CMF/Ton
"Storage capacity at 12' pile height": 10,400 Ton = 45 CFM/Ton
  - → "With addition of two 25 HP fans" (i.e. 2 bays x 5 fans = 10 fans): 560,000 cfm
"Storage capacity at 10' pile height": 8600 Ton = 65 CFM/Ton
"Storage capacity at 11' pile height": 9600 Ton = 58 CMF/Ton
"Storage capacity at 12' pile height": 10,400 Ton = 52 CFM/Ton
- → RDH notes that IVI appears to make different assumptions regarding the system pressures for the onion storage evaluation vs the previous potato design. Here the

four-fan system is predicted to deliver 464,000 cfm / 2 = 232,000 cfm per bay while in the previous storage system, the same four fans were predicted to deliver 189,000 cfm.

March 26, 2015 – IVI "Contract AAAQ3513"

- → IVI's contract for the storage system, GP2, shows a date of March 26, 2015 on the first page but a date of March 31, 2015 on the signature line.
- → The specifications section in the top right of the first page appears to indicate the same design as the first storage system with 756,000 "Total CFM"
- → However, the itemized component list in the lower section of the contract indicates:
  - → a design based on 20 fans (5 fans per storage bay)
  - → the addition of 2 SUKUP heating systems (for onion curing)
- → It appears that the total flow of 756,000 cfm listed at the top of the contract is a typo and the system, as indicated by the line items, employs five fans per bay and should be expected to deliver airflow rates as indicated in the "Onion Storage Evaluation" from the proposal.

3.3 Construction Drawings

The construction drawings or "Building Plans" for both storage systems, GP1 and GP2, were prepared by CBC Steel Buildings and stamped by D. Gao, a licensed PE in the state of Washington. These drawings are structural in nature and indicate that insulation is "by others". We did not review any drawings that provided details regarding the insulation and its installation, or air sealing that would be necessary to compartmentalize (isolate) the four separate "zones" or storage bays in each storage system.

3.4 IVI Emails

Here RDH addresses the airflow information conveyed in emails from IVI's Frank Bushman.

May 17, 2017, 6:36 pm, Frank Bushman email, "Terra Gold equipment lists and design criteria"

- → Frank Bushman, President and CEO of IVI, summarizes IVI's suggested airflow rates, refrigeration capacities, and "preferred climates" for onions and potatoes.
- → For potatoes:
  - → Airflow rate: "generally around 20 CMF per ton for potatoes"
  - → Refrigeration: "approximately one ton of refrigeration to 90 tons of potatoes"
  - → Temperature: "around 45 deg F"
  - → Humidity: "high humidity"
- → And for onions:
  - → Airflow rate: "40-60 CFM per ton for onions"

  - → Refrigeration: "approximately one ton of refrigeration to 50 tons of onions"
  - → Temperature: "around 35 deg F"
  - → Humidity: "low humidity"
  - → Mr. Bushman notes that onions can be stored in a bay that was primarily designed for potatoes, but it could only be loaded to "around 40% capacity" and claims in his email that this is "not preferred."

- → In addressing Greenpoint 1, Bays 1 thru 4:
  - → "Each zone [storage bay] incorporated 4 each 54 inch diameter fans with 25 HP 1150 RPM motors"
  - → Mr. Bushman recognizes 189,000 cfm or 21 cfm/ton of potatoes as the airflow rate that was "promised"
  - → Mr. Bushman also indicates that the fans employed should "theoretically generate between 51,000 and 57,000 CFM (per fan) or 204,000 – 228,000 CFM (per storage bay)". This represents airflow rates of 22.7 to 25.3 CFM/Ton.
  - → The higher numbers appear to correspond to those identified in the proposal as "Available system operation".
  - → Mr. Bushman states that, if the storage was used for onions, "one could load approximately 3780 tons "safely" (189,000 CFM/50 CFM per ton)" and since the fans would likely perform at a higher level as a result of less obstruction (static pressure) than the potato usage, perhaps a little over 4000 tons."

- → In addressing Greenpoint 2, Bays 5 thru 8:
  - → Mr. Bushman confirms the GP2 storage system is similar to GP1 but with 5 fans (54 inch diameter fans with 25 HP 1150 RPM motors) per bay
  - → Mr. Bushman says the additional fan "would theoretically raise the air supplied from 189,000 CFM to 236,000 CFM." RDH notes that the 236,000 CFM airflow (for 5 fans) that is indicated in this email is not consistent with the airflow indicated in the "Onion storage evaluation" that was included in IVI's Dec 11, 2014 proposal for GP2
  - → If the increased airflow (i.e. with 5 fans per bay) is 236,000 CFM, and one considers the same storage scenarios addressed in the GP2 proposal, the following airflow rates should be expected:
Onions stored at 10' pile height: 8600/2 = 4300 Ton/bay = 54.9 CFM/Ton
Onions stored at 11' pile height: 9600/2 = 4800 Ton/bay = 49.2 CMF/Ton
Onions stored at 12' pile height: 10,400/2 = 5200 Ton/bay = 45.4 CFM/Ton
RDH notes that these airflow rates are 15.8% lower than the rates that IVI presented in their Dec 11, 2014 proposal for GP2
  - → Mr. Bushman appears to walk back the expectations further, writing "the real result would likely be closer to 214,000 CFM (due to increase in static pressure) or 43 CFM per ton of onions if the higher 5000 tons were stored.

4 RDH Site Review

RDH made two trips to the TGF's Othello, WA site. RDH staff members Chris Schumacher and Maria Rumeo visited the site on July 24, 2019 for an initial site review. The weather was sunny, warm, and clear with morning temperatures near 70°F and peak daytime temperatures around 83°F. The objectives of this site review were:

- → Gain an understanding of the systems as they existed in July of 2019 (this is explained in 4.1 below)
- → Understand any deviations or changes from the original systems (these are summarized in section 4.2)
- → Identify other relevant issues to consider (these are summarized in section 4.3; RDH's observations and identification of other issues began on the first trip and continued through the second trip)

RDH staff members Chris Schumacher, Maria Rumeo, Denali Jones, David Stanton, and Xinrui (Ray) Lu visited the site to make airflow and pressure field measurements over the course of October 7-9, 2019. This second visit was coordinated to correspond to potato and onion harvests. The October 2019 airflow testing program is outlined in section 5 of this document. The airflow test results are presented in Appendix D and discussed in section 6.1.

4.1 RDH Understanding of System

The storage systems comprise:

- → An outdoor air intake, through 4 independent modulating doors (to supply fresh air),
- → a mixing chamber (to mix fresh and return air and facilitate ventilation temperature control),
- → a gas-fired heating system (GP2, bays 5-8 only) (to produce warm air to cure the onions)
- → refrigeration coils, installed as 4 coils in parallel (to cool air in recirculating mode; bypassed in fresh air mode),
- → a wall of 4 axial fans in GP1 and 5 axial fans in GP 2, installed in parallel (to drive airflow),
- → a humidification/evaporative cooler cell deck (to add moisture, increasing RH while providing evaporative cooling),
- → a supply air plenum, running the length of and beside the storage bay (to establish relatively uniform pressure at the entrance to the ducts that run under the stored crop),
- → 64 runs of 21 in. diameter spiral steel duct, running under the stored crop (to deliver and distribute conditioned air to the underside of the pile of stored crop),
- → an exhaust plenum, running the length of the storage bay, above the storage (to collect air off the top side of the stored crop),

- → a return airflow path back and feeding into the top of the mixing chamber (to facilitate return to the refrigeration coils in recirculating mode; to allow for mixing and ventilation temperature control in fresh air mode),
- → an exhaust air outlet, through louvers with gravity dampers (to facilitate exhaust of stale air when in fresh air mode)

4.1.1 Recirculation Mode

In the Full Recirculation mode all the supply air is sourced from the return plenum above the stored potato or onion stock pile, refer to Figure 4.1 below. This mode is typically applied when outdoor conditions are not favorable to reduce the temperature of the stock (i.e. in the cool down period after the crop has been brought into storage) or maintained at desired temperature (i.e. when the stock is at its final storage temperature, but outdoor conditions are warm at the beginning or end of storage season).

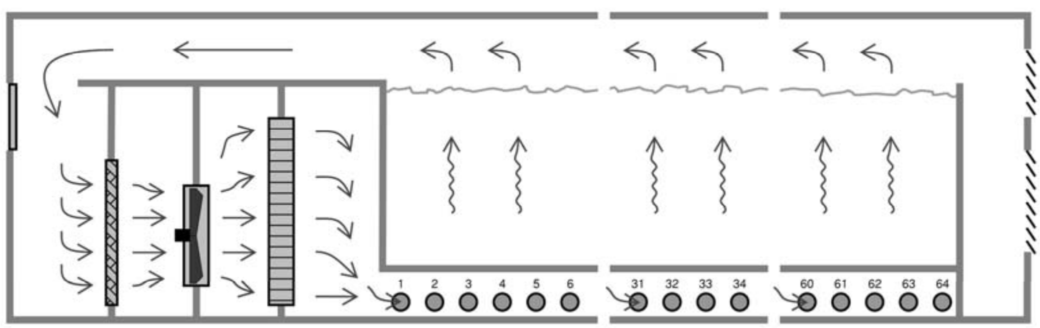


Figure 4.1 – Storage System – Cross section through a storage bay, Full Recirc Mode

4.1.2 Full Fresh Air Mode (Direct Outdoor Air Supply)

In the Full Fresh Air mode all the supply air is sourced from outside, refer to Figure 4.2 below. This mode is typically employed when outdoor conditions are favorable to provide "free cooling" of the potatoes. A similar strategy can be employed of stored onions provided the outdoor dewpoint is not higher than the desired dewpoint for the onion storage (as determined from the temperature and relative humidity setpoints currently applied.

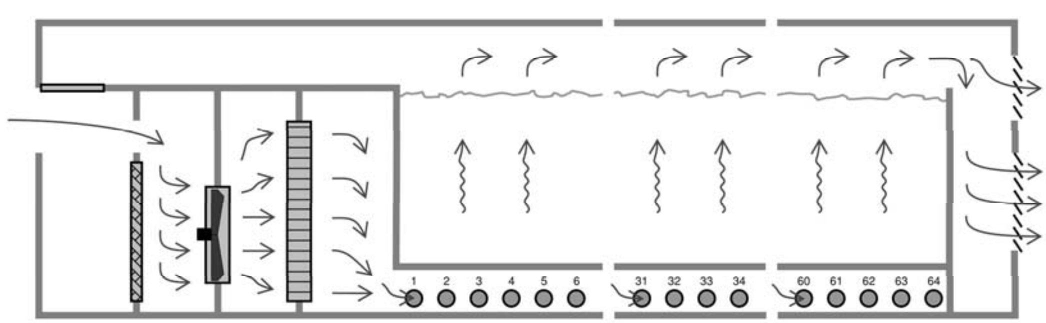


Figure 4.2 – Storage System – Cross section through a storage bay, Full Fresh Air Mode

4.1.3 Mixed Mode

Mixed modes can be applied to mix some fresh air with some recirculated or return air. This approach is employed when outdoor temperatures are too low to supply full fresh airflow to the stock. In this mode the fresh air damper positions are adjusted to mix outdoor and recirc air at the correct ratio to produce the desired delivered air temperature in the supply plenum.

4.2 Summary of Changes to Original System

AJ Ochoa and TGF's consultant, Jerry Laramore, provided RDH with a summary of changes made to address problems with the original system. These changes include:

→ ***Correction of incorrect jumper setting to repair flawed refrigeration system control configuration***

The outdoor units for the refrigeration system tended to turn on and off on relatively shot cycles. Mr. Laramore investigated this problem and discovered that the original system had been configured incorrectly: a control jumper had been configured incorrectly. The configuration error caused a miscommunication between the control system and the refrigeration system such that the refrigeration always tried to deliver double the cooling capacity that the control system requested.
This issue is addressed through further discussion in section 6.2 of this report.

→ ***Replacement of IVI's Centurion control panels***

The Centurion control panels installed by IVI, to facilitate ongoing system operation and maintenance, were reportedly replaced after IVI declined, neglected and failed to support problem investigation, diagnosis and resolution.

→ ***Redesign and replacement of humidicell deck header pipe system and pumps***

Mr. Ochoa reported that he had expressed concerns to IVI regarding frequently failing components, poor water coverage and large dry areas on the humidicell decks.
Mr. Laramore reported that he observed the same and, upon investigation determined that the system was improperly designed and installed. He designed and had fabricated and installed a different pipe header system with larger pumps.
This issue is addressed through further discussion in section 6.3 of this report.

→ ***Addition of extra, high-level exhaust louvers to address perceived problem with airflow rate and distribution***

Mr. Laramore reported that he was concerned there was too much pressure drop across the exhaust louvers. Further, he noted a lack of high-level exhaust louvers. Additional high-level louver area was added above the pile and in line with the exhaust plenum to improve exhaust effectiveness.

4.3 Additional Observations by RDH

RDH observed two concerning issues while we were on site conducting airflow testing. These issues are introduced below then addressed through further discussion in sections 6.4 and 6.5 of this report.

4.3.1 Condensation on the Ceiling

RDH was on site in Greenpoint 1, Bay 1 on October 9, 2019, testing airflow rates in a bay that was full of potatoes when we noted widespread condensation on the underside of the ceiling, refer to Figures 4.3 and 4.4 below. At that point in time the outdoor temperature was approximately 43°F while the indoor conditions were approximately 50°F and near 100% RH.

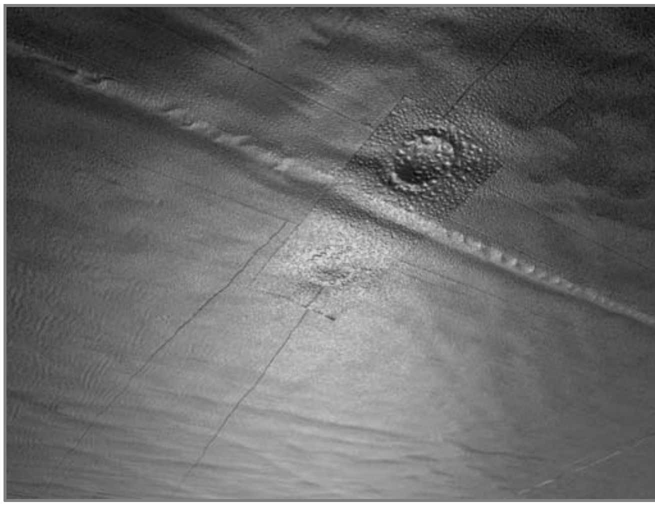


Figure 4.3 – Widespread condensation was noted on the underside of the ceiling

Figure 4.4 – No condensation was visble on the ceiling that was warmed by the light

4.3.3 Lack of Effective Compartmentalization

RDH was on site in Greenpoint 1, Bay 3 on October 8, 2019, testing airflow rates in a bay that was empty. When the Bay 3 fans were shut off we noticed a large positive pressure in the plenum on the outlet side of the fan wall and a large negative pressure on the inlet side. We were able to confirm that these pressures in Bay 3 were generated by leakage through the wall that separates Bays 3 and 4. Numerous air leakage paths were identified. Further investigation revealed that, while IVI had sealed some interface joints using methods such as closed-cell spray polyurethane foam (e.g. at the wall-to-ceiling and wall-to-mezzanine interfaces), other joints were large and completely lacking seals. (e.g., the gap under the person doors between the two bays).

Figure 4.5 – Large gaps under doors between pairs of storage bays

Figure 4.6 – Long, narrow gaps exist at wal-to-wall interfaces. Light can be seen straight through these

5 RDH Field Testing

RDH devised an airflow test program to characterize and quantify the airflow rate, distribution, and pressure field under scenarios to facilitate an assessment of the performance of the original systems. Results of RDH's October 2019 Airflow Testing program are presented in Appendix D.

5.1 Approach

Total system airflow measurements were made by way of a velocity traverse on the downstream side of the humidicell deck. The air pressure field was characterized using a network of micromanometers with pressure taps allocated to measure pressure drop or lift across each major component in the airflow network.

5.2 Scenarios

Operating Modes

The RDH Airflow Test Program was designed to evaluate aiflow and pressure drop through the three storage bays when they are running under their two primary operating modes: full recirculation and full fresh air (i.e. no mixing).

Louver Modifications

Further testing was conducted to assess the impact of the additional louvers had on the airflow rate and pressure distribution when the system was running in full fresh air mode.

Empty vs Full Bays

The RDH Airflow Test Program was applied to storage bays under three conditions:

→ Bay 3: an empty 4-fan bay (Figure 5.1)

→ Bay 1: a 4-fan bay that was full of potatoes (Figure 5.2)

→ Bay 5: a 5-fan bay that was full of onions (Figure 5.3)

In testing storage bays under these three conditions we can assess whether the storage system can provide enough airflow, and what the prevailing static pressure is, when the bay is empty; when it is full of potatoes, and when it is full of onions.

Figure 5.1 – GP1, Bay 3, Empty, with 20 distribution ducts installed and 44 duct entrances fully open to maximize airflow

Figure 5.2 – GP1, Bay 1, full of Potatoes

Figure 5.3 – GP2, Bay 5, full of Onions

6 Discussion

RDH has identified five (5) issues that, in our opinion, negatively impact the performance of the storage systems and caused or substantially contributed to the crop failures that TGF reported in 2015 and 2016. These are addressed individually in the sections that follow.

6.1 Airflow Deficit

TGF and their consultant, Jerry Laramore, were both concerned that the delivered (in service) airflow was lower than stated in IVI's design (proposal) and contract, and that the static pressure was higher than stated in IVI's design (proposal) and contract. In other words, there is an "airflow deficit".

RDH conducted field measurements to verify the in-service airflow rates.

6.1.1 Measured Airflow in Bay 3 – Empty

When a storage bay was tested empty (Bay 3, with ducts installed in 20 of the 64 openings and the remaining 44 wide open) the total airflow rates under 100% recirc and 100% fresh air modes were 152,000 and 139,000 cfm respectively. The measured airflow rates are approximately 20 and 26% below the rate that was promised in the proposal and contract. These would work out to approximately 17.0 cfm/Ton of potatoes in 100% recirc and 15.5 cfm/Ton in %100 fresh air mode (i.e. with refrigeration coils bypassed). This is below contractual performance specifications and below accepted industry standard airflow rates for potatoes. Fan and system pressures were measured at the same time. The measured fan pressures for 100% recirc and 100% fresh air were 1.34" SP and 1.44" SP respectively. With the bay empty and with only some ducts installed, static pressure should have been lower, not higher, than the 1.25" of static pressure stated by IVI in its proposal and contract.

6.1.2 Measured Airflow in Bay 1 – Potatoes

RDH repeated the airflow field measurements on Bay 1 which was full of potatoes. The total airflow rates under 100% recirc and 100% fresh air modes were 161,000 and 144,000 cfm respectively. If 9000 Tons of potatoes are stored the measured airflow rates work out to approximately 17.9 cfm/Ton of potatoes in 100% recirc and 16.4 cfm/Ton in %100 fresh air mode (i.e. with refrigeration coils bypassed). This is below contractual performance specifications and below accepted industry standard airflow rates for potatoes. The measured fan pressures for 100% recirc and 100% fresh air were 1.45" SP and 1.62" SP respectively. Static pressure is significantly higher than the 1.25" stated in IVI's proposal and contract.

In recirculation mode the measured airflows are roughly:

→ 11% below the 20 cfm/Ton delivery rate that is typical for current industry guidance;

→ 15% below the 21 cfm/Ton delivery rate identified in IVI's proposal and contract; and

→ 30% below the "Available System Operation" that was indicated in IVI's May 17, 2017 email.

In full fresh air mode the measured airflows are approximately:

- → 18% below the 20 cfm/Ton delivery rate that is typical for current industry guidance;
- → 22% below the 21 cfm/Ton delivery rate identified in IVI's proposal and contract; and
- → 35% below the "Available System Operation" that was indicated in IVI's May 17, 2017 email.

6.1.3 Measured Airflow in Bay 5 – Onions

RDH repeated the airflow field measurements on Bay 5 which was nearly full of onions (there were two types of onions stored with an area in the middle where the pile was only about 6 ft. high). Bay 5 is in the second storage system, Greenpoint 2 (GP2). The storage bays in GP1 only employ 4 axial fans per bay. The storage bays in that GP2 were designed to produce higher airflows as required for the storage of onions; hence they employ 5 axial fans per bay.

The total airflow rates under 100% recirc and 100% fresh air modes were 205,000 and 188,000 cfm respectively. If onions are stored to a pile height of 12 ft. we would estimate the mass to be 5200 Tons (as suggested in IVI's December 11, 2014 proposal for GP2). The measured airflow rates then work out to approximately 39.4 cfm/Ton of onions in 100% recirc and 36.2 cfm/Ton in %100 fresh air mode (i.e. with refrigeration coils bypassed). This is below contractual performance specifications and below accepted industry standard airflow rates for onions. The measured fan pressures for 100% recirc and 100% fresh air were 1.62" SP and 1.65" SP respectively. Static pressure is again significantly higher than the 1.25" stated in IVI's proposal and contract.

In recirculation mode the measured airflows are roughly:

- → Just meeting the bottom end of the 40-50 cfm/Ton range of delivery rates that are typical for current industry guidance;
- → 14% below the 52 cfm/Ton delivery rate identified in IVI's proposal and contract; and
- → 8-13% below the 43 and 45.4 cfm/Ton that are associated with Mr. Bushman's range of expected performance from IVI's May 17, 2017 email.

In full fresh air mode the measured airflows are approximately:

- → 18% below the 40-50 cfm/Ton range of delivery rates that are typical for current industry guidance;
- → 30% below the 52 cfm/Ton delivery rate identified in IVI's proposal and contract; and
- → 16-20% below the 43 and 45.4 cfm/Ton that are associated with Mr. Bushman's range of expected performance from IVI's May 17, 2017 email.

6.1.4 Impact

In summary, RDH measured airflow deficits (i.e. airflow rates below what was contractually promised, and below accepted industry standards) in GP1, Bay 3 (empty, at 20-26% deficit); GP1, Bay 1 (potatoes, at 11-35% deficit); and GP2, Bay 5 (onions, at 8-30% deficit).

The low airflow rates are meaningful. In their paper "Temperature and Airflow – two aspects of potato storage management", Oberg and other authors from University of Idaho relate the story of a system that was operating at an airflow that was reduced 7% below intended, an airflow deficit that is as much as 5x smaller than the airflow deficits RDH measured in Greenpoint 1, Bays 1 and 3, and Greenpoint 2, Bay 5. Oberg et al. deemed the 7% deficit to be problematic because it increased operating cost and reduced "the product quality benefits associated with proper airflow."

Finally, low airflow rates are problematic when they prevent delivery of enough oxygen, proper distribution of that oxygen, and effective removal of CO2 produced through respiration of the stored vagetables.

6.1.5 Cause of Inadequate Airflow

The measured airflow deficits result from the design of the systems.

RDH believes the fans are Multi-Wing 54/6-6/30°/PPG/9WL with 25 HP Teco Westinghouse motors that rotate at approximately 1150 RPM. The Multi-Wing Optimiser software (10.0.5.66) produces a fan curve for this fan (at an elevation of 300 m, with an air temperature of 15°C, and an orifice plate inlet) that supports IVI's assertion of 50,000 cfm flow per fan at 1.25" SP. However, RDH is confident in its field measurements and our conclusions:

→ the in-service airflow rates for the 4 fan systems (i.e. GP1, Bays 1-4) are 15-20% lower than contracted and 11-18% lower than industry guidance (for potatoes); and

→ the in-service airflow rates for the 5 fan systems (i.e. GP2, Bays 5-8) are 14-30% lower than contracted and up to 18% lower than industry guidance (for onions).

The design of the HVAC system is directly responsible for the low airflow. The arrangement of the fans and geometry of the airflow path on the inlet and outlet side of the fan wall result in "System Effects" that reduce the effectiveness of the fans. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Systems and Equipment Handbook (2008) explains

> *Normally, a fan is tested with open inlets, and a section of straight duct is attached to the outlet. This setup results in uniform flow into the fan and efficient static pressure recovery on the fan outlet.*
>
> *If good inlet and outlet conditions are not provided in the actual installation, fan performance suffers. To select and apply the fan properly, these effects must be considered and the pressure requirements of the fan, as calculated by standard duct design procedures, must be increased.*

System effects and methods to account for them are addressed in the Air Movement and Control Association International (AMCA) document 201-02 (R2011), "Fans and Systems".

When system effects are involved one cannot rely on air pressure measurements and fan curves to estimate airflow.

There are several design factors that result in reduced airflow at the Greenpoint sites: the Fan Arrangement; the Fan Bank Inlet Flow Path; the Humidicell Outlet/Plenum Inlet Flow Path; and the Exhaust Louver Flow Path.

Fan Arrangement

The arrangement of the fans can be expected to create a system effect. The systems at GP1, Bays 1-4, each have four 54 in. diameter fans installed in a fan wall that is 29 ft. wide. This results in 20 in. wide spaces between the fans. GP2, Bays 5-8, each have 5 fans, so they are installed at an even tighter spacing (only 6 in.) When axial fans are installed close together in a parallel arrangement like this, they compete for air on the inlet side, a system effect is realized, and the performance is reduced.

AMCA 201-02 provides the following guidance that has relevance to the systems at Greenpoint: "For proper performance of axial fans in parallel installations minimum space of ***one impeller diameter*** should be allowed between fans. Placing fans closer together can result in erratic or uneven airflow into the fans." (text effect added for emphasis).

In spaces like the fan walls at GP1 and GP2, where there isn't room to leave a one impeller diameter space (in this case 54in.) between fans, the designer should account for the system effect and apply a reduced airflow to the system design.

Fan Bank Inlet Flow Path

AMCA 201 also cautions that "***The total performance of the multiple fans will be less than the theoretical sum*** if inlet conditions are restricted or the airflow into the inlets is not straight." (text effect added for emphasis).

When the storage bays at Greenpoint are operating in recirculation mode and the refrigeration system is required, air will be drawn through the cooling coils (which also act as flow straighteners) so it travels in a straight (approaching optimal) flow path. In this case there would be little system effect due to the inlet flow path.

However, when the refrigeration system is not in use and the air enters the inlet plenum through the bypass doors above the cooling coils, it must enter through the bypass, turn and drop down 6-8 ft., then turn again as it is drawn into the fan inlets, refer to Figure 6.1 below. These tightly spaced changes in airflow direction will result in spin and swirl, so the inlet airflow will not be straight and the fan performance will suffer. This phenomenon likely explains why RDH measured lower airflow rates for the full fresh air scenarios.

Again, this is a condition that designers should watch to avoid (by changing geometry), or to recognize and account for by de-rating the airflow of the system.

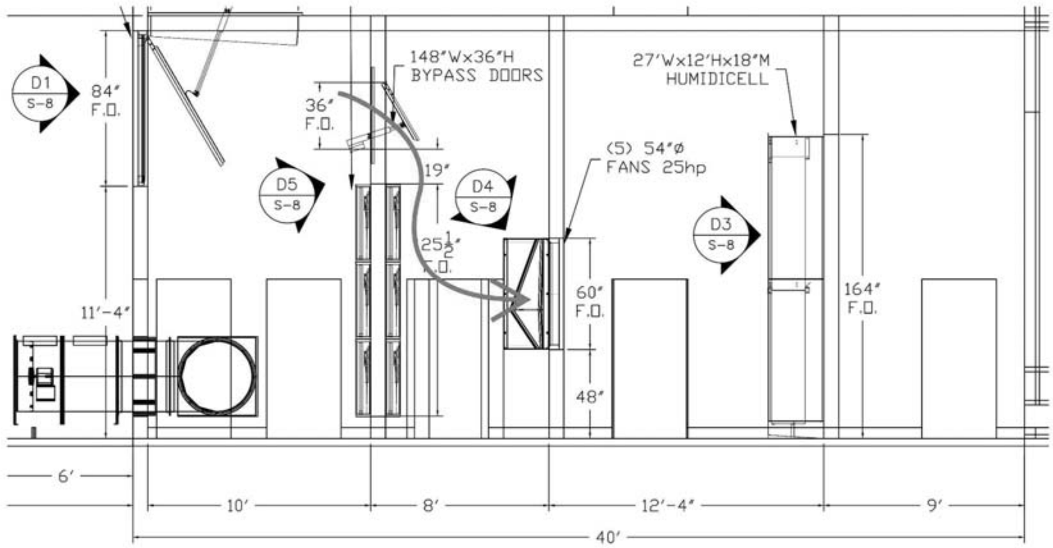


Figure 6.1 – Horizontal section of fan house showing inlet airflow path, fresh air mode

Humidicell Outlet/Plenum Inlet Flow Path

A similar geometry issue exists on the outlet flow path from the fan bank, and as it enters the plenum inlet. As air leaves the humidicell deck it can only travel 9 ft before abruptly running into a wall and being forced to run against it before it abruptly turns again as it is thrust into the center wall of the supply plenum, refer to Figure 6.2 below. Only a small portion of the humidicell deck is aligned with the supply plenum. It is in this area that RDH measured the highest velocities off the face of the cell deck and the lowest pressure drop along the path to the start of the supply plenum.

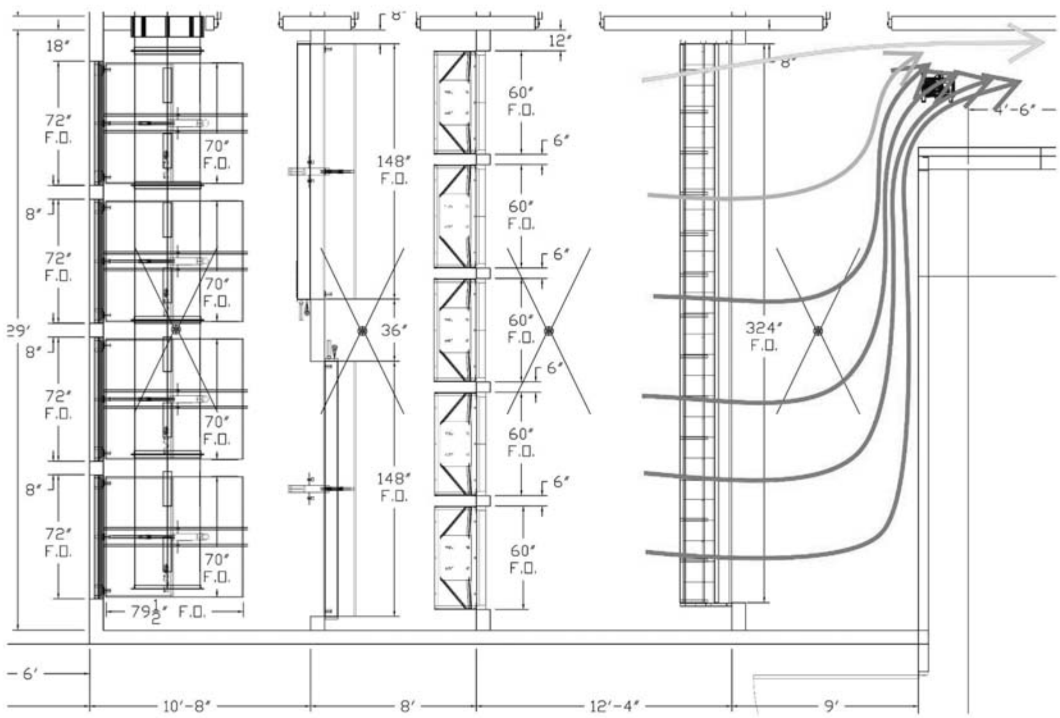


Figure 6.2 – Plan view of fan house showing airflow paths out of cell deck, all modes

The humidicell outlet/plenum inlet geometry may impact the fans as a system effect, or it may impact the system as a messy "fitting loss", or it may do both. Regardless, it is clear that the geometry creates airflow inefficiencies that should, and would by a reasonably competent system designer, be considered and accounted for in the design, configuration, installation and commission of the system.

RDH notes that, because the flow pattern at the plenum inlet favors flow against the center wall of the supply plenum (rather than evenly across the width of the plenum) the first few (2-3) distribution ducts are not served as effectively as those further down the plenum. RDH confirmed this through the measurement of center-of-duct flow velocities on the first few ducts.

Plenum Exhaust/Exhaust Louver Flow Path

Finally, a similar geometry issue exists on the at the far end of the exhaust plenum. There, air is forced to collect on the mezzanine side of the storage bay and travel to end mezzanine where it abruptly drops down into the stairwell/exhaust tower and turns hard one last time to leave through the exhaust louvers. Mr. Laramore addressed this problem through the installation of additional louver area above the pile and in line with the exhaust plenum to improve exhaust effectiveness. RDH tested full ventilation airflow with these additional louvers masked (i.e. to replicate the original exhaust airflow configuration) and with them open. The additional exhaust louver area was demonstrated to increase overall flowrates by 5-13%.

6.1.6 Overall System Geometry, Commissioning, and Responsibility

For the reasons stated above, the overall system geometry was defectively designed, configured and installed. Reasonably competent, skilled, prudent vegetable storage system designers and installers should be aware of the possible negative effects of system geometry on airflows, even air distribution, and static pressures, and of resulting negative system effects, and should account for such effects in the design, configuration, and installation of the system and its components. IVI failed to do so here and, in our opinion, the system was defective and IVI fell below the standard of care in its design, configuration and installation.

In their commissioning work we would have expected IVI to measure the delivered flow to confirm it is within that specified in the proposal and contract. Had they done this IVI technicians would have been made aware of the fact that the flow rate was lower than intended. They would then have a chance to diagnose and correct the problem or at least to advise TGF of a necessary reduction in storage capacity. The failure to test/commission the system prior to turning it over to the customer also, in our opinion, fell below the standard of care, in addition to the improper/defective geometry of the system design.

6.2 Erroneous Refrigeration Control Settings

RDH understands that TGF's consultant Jerry Laramore identified and repaired a flaw in the refrigeration control calibration. The error presented as a control jumper that was set to the wrong position. As a result, analog control signals from IVI's Centurion Control system were sending a 0-10 volt signal to request 0-100% cooling, while the refrigeration system was calibrated at a 0-5 volt signal to provide 0-100% cooling.

The calibration error caused the refrigeration system to supply 100% cooling capacity anytime the Centurion System requested at least 50% of capacity. When the Centurion System requested less than 50% the refrigeration system would supply cooling at a rate of double the request. For example, a request for 30% would be met with cooling supplied at 60% of full capacity.

6.2.1 Impact

This control calibration error and its impact could be replicated now but to do so would compromise the environmental conditions in the storage bays and jeopardize the quality of the stored onions or potatoes. However, we know this type of error will result in, among other issues, overcooling of the coils and supply air, and erratic response of the system. These are explained further in the text that follows.

Overcooling of the coils and supply air

When the refrigeration system responds with too much capacity the coils are cooled very quickly, causing them to reach temperatures that are lower than intended (i.e. they are overcooled). This may cause them to collect frost or ice more quickly than expected. Frequent icing will require more frequent defrost, increasing energy demand and compromising system climate control. Defrosting the coils adds moisture to the air directly ahead of the fan bank. Particularly in onion storage, this can create problems in controlling and maintaining low humidity levels.

In those situations where frosting does not become excessive there is still the problem of air being delivered at temperatures that are cooler than intended. For these storage applications overcooled supply air can be a serious problem. Ideally the supply air is delivered to the bottom of the potato or onions stock with just enough temperature difference to provide cooling to the pile. If the temperature difference between the supply air and the stock becomes too large it will impact the moisture conditions in the pile. When cold air meets the surface of the vegetable a thin layer of air, right next to the surface of the vegetable, is heated. This causes the temperature of the air to go up and its relative humidity to drop. If the drop in RH is too great, the air will cause excessive drying of the stored potatoes or onions.

Erratic response of the system

When the air is cooled at a rate that is much faster than the system expects, it will reach and exceed setpoints and temperature limits too quickly so the system will respond by shutting down the refrigeration. This will cause the system to short-cycle. In other words, it will turn on and off frequently, running only for short periods of time. This is a

symptom that the Ochoas noted (Outdoor refrigeration or condensing units turning on and off on short, frequent intervals).

The impact of short cycling may not be evident in historic data if that data is measured at or averaged over longer periods of time (i.e. 30 minutes, 1 hour, several hours, or days). Short-cycling typically shows up at data cycles that are less than 5 minutes in length.

As previously mentioned, the RH at the surface of the potatoes and onions can be impacted by fluctuations in supply air temperature. Every time the temperature of the supply air cycles down, cold air is introduced to the storage area. Heat from the vegetables increases the temperature of the air at the surface of each potato or onion, causing the relative humidity of that air film to decrease. Conversely, when the temperature of the supply air cycles up, warm air is introduced to the storage area. The cool vegetables reduce the temperature of the air at the surface of each potato or onion causing the relative humidity of that air film to increase. If the air warms quickly (as it might with a sudden shut down of the refrigeration system) and is still maintained at high RH (as intended), condensation may occur on the coldest of the potatoes or onions.

The Pacific Northwest extension document PNW 257 cautions against rapidly changing and fluctuating temperatures “Avoid rapid temperature changes. Fluctuating temperatures are also undesirable; they can cause early sprouting and increase weight loss.”.

The Canadian Horticultural Council document entitled “Control of Potato Storage Conditions for the Management of Post-harvest Losses due to Diseases” cautions against fluctuations in RH: “avoid fluctuations in RH which stress the tubers and can lead to condensation problems, maintaining a uniform temperature is essential.”.

There is co industry-consensus on the need to maintain stable or at least slowly changing temperature and humidity conditions.

6.2.2 Responsibility

Properly setting, and double-checking, system demand and response settings is a simple, but fundamentally necessary function of a properly installed and operating system. Here, IVI failed to calibrate the response setting correctly, and failed to check that the settings of the Centurion system control panel, and the setting of the refrigeration control panel were calibrated to match each other. This resulted in a serious defect in the system as installed, and a defect in its proper functioning. In our opinion, the failure to properly set and double-check the refrigeration demand and response settings fell below the standard of care of a reasonably competent, skilled, and prudent designer and installer of these types of systems. The IVI system installers also should have identified this error through their testing/commissioning process or at least through review of short-cycle temperature, humidity, and motor runtime during the first days of operation. Had IVI technicians identified this pattern, they would have been able to trace it back to the flawed signal and response, then address it easily by adjusting the setting to the correct position. The failure to do so also fell below the standard of care of a reasonably competent, skilled, prudent vegetable storage system designer and installer. As a result, the system was defectively installed and defectively functioning. The error in this case occurred across all bays in both GP1 and GP2.

6.3 Poor HumidiCell Deck Hydration

RDH understands that there were numerous problems with operation of the humidicell deck over the time period when the storage failures were reported. TGF's consultant, Jerry Laramore, explained that IVI had replaced several failed pumps and yet they were still having problems with maintaining hydration of the cell deck. Mr. Laramore reported there were frequent periods when a large area of the cell deck was visibly dry.

Mr. Laramore explained that the original system comprised 2 header pipes, each fed by a water pump at one end and intended to cover the length of the humidicell deck.

Mr. Laramore replaced the original system with a 3 pipe header system to get better coverage across the depth of the humidicell. The header was divided into left and right circuits instead of front and back circuits. Larger pumps were installed to ensure that the headers were full and sufficient water was delivered to ensure the cell deck was saturated through its full thickness, width, and height.

RDH did not witness the original humidicell pumping and header distribution system in operation so we are unable to comment on its effectiveness. However, we can comment on the impact of a poorly hydrated humidicell deck, which more probably than not was the case based on the information we received.

6.3.1 Impact

The humidicell deck system plays a key role in the climate control system, especially in the storage of potatoes. This humidicell deck is large-area evaporative cooling pad that can increase the air moisture content without the addition of heat. When ventilation air is warm and dry the humidicell will provide a significant amount of evaporative cooling.

If the humidicell deck was not sufficiently hydrated, i.e. to the point that water droplets cover the entire surface, from front to back, side to side, and top to bottom, then the system may not provide enough humidification. When the relative humidity cannot be maintained by the humidicell deck, the operators must attempt to add more moisture using spinners or centrifugal humidifiers. The centrifugal humidifiers are less desirable because they tend to put larger droplets or free water into the air. Poor and unreliable hydration of the humidicell deck forces more frequent and longer operation of the centrifugal humidifiers for humidity control. That increases the amount of free water available and increases the risk for disease in the stored tubers.

Similarly, poor and unreliable hydration of the humidicell deck compromises evaporative cooling and forces greater reliance on the refrigeration system. The Washington State University extension document EM2799 encourages the use of evaporative cooling: "the size of the refrigeration system as well as the cost of operation can be reduced by making full use of night air and evaporative cooling." The climate of Othello WA is dry so evaporative cooling is effective for many weeks during the fall and early summer. Significant cost savings are lost when the humidicell cannot be maintained with enough hydration to support evaporative cooling.

6.3.2 Responsibility

RDH understands that the original humidicell hydration system configuration has been used on smaller humdicell deck installations and that TGF staff have experience with some of those systems. TGF raised concerns to IVI regarding poor humidicell deck hydration at the Greenpoint facilities. Further, IVI maintenance staff had to replace failed humidicell pumps on more than one occasion. When IVI staff were faced with repeat problems on the humidicell systems at Greenpoint 1 and 2 they should have recognized the possibility that this was a design problem and should have reconsidered and modified the systems.

In our opinion, a humidicell deck that is inefficient and ineffective constitutes a major defect in the system with regard to both the ability to control and maintain humidity and temperature. Accepting as correct the information we received regarding the inability of the pumps and distribution pipes as designed, configured and installed by IVI to maintain adequate water supply and distribution across and through the entirety of the cell deck, in our opinion the humidicell deck was therefore defective in design, configuration and installation. Selection of properly sized and configured components is a fundamental requirement of proper system design, installation and operation. The failure to do so fell below the standard of care of a reasonably competent, skilled and prudent designer and installer of the type of systems at issue here. Likewise, proper and thorough testing and commissioning of the system before turning it over to the customer should have been done, and would more probably than not have identified this problem. The failure to do so also fell below the standard of care.

6.4 Ceiling Insulation and Condensation

RDH observed widespread condensation on the ceiling in GP1, Bay 1 during our October 9, 2019 site visit. At the time the bay was full of potatoes and the system was maintaining roughly 50°F and near 100% RH. The IVI proposals indicate that the ceilings are insulated with R-40 blown-in fiberglass and 1in. of foil-faced foam board on the underside. Foil-faced foam board can be justified as a design choice because it isolates thermal bridging of the steel structure, it acts as a vapor barrier, and it makes an easy and inexpensive ceiling air barrier (when implemented with foil-tapped joints). However, it also likely increases the frequency of ceiling condensation.

Foil-facers are applied to board insulation to present a low emissivity surface (estimated to be in the range of 0.05 to 0.2) that will reduce radiant heat transfer across adjacent air spaces. This improves the thermal performance of the insulation, but it also makes the surface colder than a surface that exhibits a typical building product emissivity of 0.9.

6.4.1 Impact

The impact of the foam can be seen the surface film coefficients published in the ASHRAE Handbook of fundamentals (HOF 2017, Chapter 26, Table 10).

For heat transfer upward (e.g. from warm potatoes to a cold ceiling), the air film on a non-reflective surface can be expected to present an R-value of R-0.61. Under the same

scenario the air film next to a reflective foil surface can be expected to present an R-value of R-1.10 to R-1.32.

The ceiling surface temperature and condensation potential can be estimated by considering the heat flow through the assembly and the temperature drop across the ceiling air film. If the storage climate conditions are 50°F and 98% RH, then the indoor dewpoint is 44.5°F. Condensation is predicted to occur on non-reflective surface whenever the ambient temperature falls below 8°F; and on a reflective surface when the ambient temperature falls below 28°F. The reflective (foil-faced) ceiling would experience many more hours of condensation.

The 1993 reprint of the Washington State University Cooperative Extension, bulletin EM2799, "Potato Storage and Ventilation" cautions storage designers: "With high relative humidities the dew point is nearly as high as the ambient temperature. Thus, a surface only slightly cooler than the surrounding air will cause condensation.".

If condensation droplets get too large there is a risk they will fall onto the pile and the liquid (free) water might initiate decay or other biodeterioration. To prevent this, operators run electric heaters and fans at the ceiling. While these can effectively dry moisture from the ceiling, they also increase energy use and add heat load to the ventilation system, potentially compromising temperature control.

6.4.2 Responsibility

IVI designers should have been aware of the effect that low-emissivity surfaces such as foil will have on surface temperatures, dewpoint on the surface of the foil, and the likely issue of free water droplets falling to the pile. Factory-painted foam boards could have been specified, purchased (for less money) and applied to reduce the potential for condensation.

In our opinion, reflective foil ceiling insulation should not have been used in this application and likely contributed to problems controlling temperatures within the system and, based on our observations, likely resulted in condensation on the insulation and free water falling to the pile. This constituted a defect in the system. In our opinion a reasonably competent, skilled and prudent designer and installer of this type of system should not have and would not have used or installed this type of foil ceiling insulation, and it fell below the standard of care to do so.

6.5 Incomplete/Inadequate Compartmentalization

IVI's literature represents, and its contracts promised, the storage bays as independent zones. Independent zones permit the storage of different goods in adjacent storage bays; they permit the operation of systems on different schedules; they facilitate the maintenance of different climate conditions on either side of the center wall. These processes result in large air pressure differences across the center wall between two storage bays (zones). Where there are small holes or leakage paths, air will be moved from one side to the other.

As described above, although IVI claimed that each bay was an independent storage zone, in fact they were not sealed off from each other. Our inspection revealed various leakage points between bays. There may be others. For example, we understand that Jerry Laramore tested and discovered air transfer between bays in the drainage systems. Like the leakages we observed, combined drain systems would also compromise the independence of each storage zone (bay).

Figure 6.1 – Dry air, pulled from an empty bay, through a door undercut on the mezanine level, has evaporated moisture from the deck in a bay full of potatoes, providing a visual indication of the lack of compartmentalization and the occurance of air leakage

The spray foam air seal is visible along the base of wall

Figure 6.2 – When fan systems are run at high speed, high pressure differences are developed and air is pulled from the adjacent storage bay, through the floor drains, carrying water with it

6.5.1 Impact

Uncontrolled air movement (air leakage) can be problematic in potato and onion storages because leakage between bays can carry moisture and other contaminants (e.g. airborne bacteria, fungi, etc.), divert airflow (another system effect), and make independent temperature control more difficult, compromising environmental control and product quality in each bay.

6.5.2 Responsibility

It is essential that adjacent zones be compartmentalized (air sealed) to prevent air leakage and the transfer and mixing of moisture, temperature, chemicals and contaminants between bays. IVI should have accounted for these obvious leakage paths in their design. The failure to provide independent zones by ensuring proper and effective air barrier systems and seals, and that the bays were fully independent of each other environmentally, constituted a defect in the system, and also failed to provide what the contract promised. In our opinion a reasonably competent, skilled and prudent designer and installer of this type of system would have designed and installed the system to account for and adequate seals between the bays, and it fell below the standard of care not to do so.

7 Conclusions

RDH makes the following conclusions:

→ The Greenpoint 1 and Greenpoint 2 storage facilities are specialized vegetable storage systems. The geometry of the structure, the layout of the plenum spaces within, and the high level of integration between the enclosure, monitoring, control, and conditioning systems (in function as well as form) results in a climate-controlled vegetable storage system product that was designed, manufactured, assembled, installed, configured and commissioned by IVI.

→ Industrial Ventilation Inc. was negligent in their design, assembly, configuration and installation of the GP1 and GP2 storage systems/facilities.

  → IVI failed to recognize and account for HVAC system geometries that produced negative system effects deficient airflow rates. The in-service airflow rates for the 4 fan systems (i.e. GP1, Bays 1-4) are 15-20% lower than contracted and 11-18% lower than industry standards for potatoes; the in-service airflow rates for the 5 fan systems (i.e. GP2, Bays 5-8) are 14-30% lower than contracted and up to 18% lower than industry standards for onions.

  → IVI failed to design, configure and install a functional and reliable water distribution system for the humidicell deck.

  → IVI failed to recognize the increase in ceiling condensation risk that is associated with the selection of an insulation board that uses a reflective (low emissivity) foil insulation, and the effect that type of insulation has on temperature control.

  → IVI failed to design a complete or adequate compartmentalization system (independently zoned bays) to prevent uncontrolled airflow (air leakage) between adjacent storage bays.

→ Industrial Ventilation Inc. was negligent in their assembly, commissioning, maintenance and servicing of the Greenpoint 1 and Greenpoint 2 storage facilities.

  → IVI failed to effectively commission the fan systems at GP1 and GP2. They did not identify an airflow deficit and missed an opportunity to either address the problem or warn TGF of the problem so they may avoid risking crop in an ill-functioning storage facility.

- → IVI failed to properly commission the refrigeration systems at GP1 and GP2. They did not recognize a cooling rate problem nor identify a flawed condition in the control settings for the cooling systems.
- → IVI failed to diagnose and address the humidicell deck water distribution systems.
- → IVI failed to complete effective air sealing required to compartmentalize adjacent storage bays so they would be truly independent.

The foregoing issues and problems constituted defects in the design, assembly, configuration, and installation of the vegetable storage systems, breached contractual performance obligations, and fell below the standard of care of a reasonably competent, skilled, and prudent designer, assembler, and installer of these types of vegetable storage (environmentally controlled) systems.

8 COMPENSATION

RDH has been and is being compensated for its work in this matter on a time and expense basis. Find in Appendix C, our rate sheet for our services. As of the end of October 2019 we have invoiced approximately $72,000 in fees and $8,500 in expenses. We expect to invoice approximately an additional $20,000 for our efforts in the month of November 2019.

We trust this report meets your current needs. Please contact us should you have any questions regarding this report.

RDH reserves the right to revise or update these conclusions based on new information.

Yours truly,

C J Schumacher Digitally signed by C J Schumacher
DN: C=CA, E=cschumacher@rdh.com, CN=C J Schumacher
Date: 2019.11.18 19:11:19-05'00'

Chris Schumacher | M.A.Sc, B.Tech.
Principal, Sr. Building Science Specialist
cschumacher@rdh.com
519 504 4157
RDH Building Science Inc.

Rob Bombino | M.S. P.E. (WA, MA)
President, Sr. Building Science Specialist
Reviewed by

Appendix A – RDH Staff Biographies

RDH BUILDING SCIENCE

Chris Schumacher | M.A.Sc.

Principal, Senior Building Science Specialist

Christopher Schumacher is recognized as an expert in the field of building monitoring, as well as enclosure and building systems testing. He has led the design, installation, and analysis of monitoring systems for a variety of research programs and demonstration projects, both in the lab and in field locations around the globe.

Expertise + Experience

Chris' formal education in architecture and engineering is balanced by two decades of experience in design, computer simulation, physical testing, and forensic investigation. He oversees much of the work done through RDH Building Science Laboratories, and regularly participates as a consultant in the development of experimental test programs for academic institutions, building product manufacturers and government agencies including DOE, EPA, CMHC, NRC/IRC, NRCan and UNDP. Examples of his research work include a multi-year investigation of thermal performance in full-scale wall assemblies (the Thermal Metric Project) and development of an apparatus and test method to measure dense-pack airflow resistance, to support development of the Building Performance Institute's test standard BPI-103 and material standard BPI-102. He has played key roles in and received awards for several major ASHRAE research projects. He has extensive experience in product testing and development and thrives on the challenge of inventing novel solutions to client and industry questions.

Before joining RDH Building Science Inc., Chris was a founding principal of Building Science Consulting Inc., and previously a founding partner of Balanced Solutions Inc., an innovative Canadian building science RD&D consultancy. His expertise has been instrumental in analyzing and remediating condensation damage in attics, mold in walls, peeling paint, failed masonry and poorly performing HVAC systems in houses, schools, office buildings and industrial facilities. Chris' combined interest in research and practice, and in the connections between the two, reflects his commitment to the continuous development of building science.

Chris is a Principal of RDH Building Science Inc. and has over 20 years' experience as a building scientist.

Education

M.A.Sc., Civil Engineering Dept., University of Waterloo, ON

B.A.Sc., Civil Engineering, University of Waterloo, ON

B.Tech., Architectural Science, Ryerson Polytechnic University, Toronto, ON

Memberships

Member, Ontario Building Envelope Council (OBEC)

Typical Projects

RESEARCH + FORENSICS

Chris was the lead building science consultant on the following projects:

- Dunning Place, Regina, SK – Provided building science testing and consulting services for this historical load-bearing masonry office building. Performed material property tests, used to calibrate a hygrothermal model. Simulations were conducted to develop options for an interior insulation retrofit to reduce energy use, and improve thermal comfort.
- Google Building Retrofit and Restoration, New York, NY – In collaboration with Building Science Corporation, building science consulting services were provided to develop a master plan for the energy retrofit and redevelopment of this 2.9 million sq. ft. historic concrete and brick masonry building. Scope included material testing, hygrothermal simulations, and construction of prototype retrofits.
- Halifax Armoury Building, Halifax Nova Scotia – Collected and analyzed data related to freeze-thaw risk assessment. As a designated Historical site, all rehabilitation of the masonry assemblies and the whole building were of utmost concern. Tasks included field review of building enclosure conditions, enclosure monitoring, analysis, and reporting.

Chris provided building science research and consulting services for the following projects:

- Thermal Metric Project – Oversaw the implementation of a multi-year research program investigating thermal performance in full-scale wall assemblies, with the goal of

RDH BUILDING SCIENCE

Chris Schumacher | M.A.Sc.

Principal, Senior Building Science Specialist

developing alternatives to the R-value. Managed the design, construction, commissioning, and operation of the Thermal Metric Double-Guarded Hot Box.

- Vancouver Test Hut Project – Lead consultant for experimental design and setup of the Vancouver Test Hut, a field exposure facility used for a multi-year investigation of wall assembly performance in a Pacific Northwest climate.
- U.S. DOE Building America High Impact Project, Support of Standards Development: Dense-pack Airflow Resistance (final report completed Nov. 2011) – Oversaw the development of an apparatus and test method designed to act as the basis for the Building Performance Institute's test standard BPI-103 and to inform material standard BPI-102.
- Historic Masonry Building Retrofit Guidelines (United States Military Academy) – Lead consultant providing guidance on insulation retrofit strategies for a historically significant group of 86 masonry buildings.
- Frederic C. Hamilton Building, Denver Art Museum, Denver, CO – Provided expert peer review of proposed plans to remedy moisture and condensation problems for this 146K SF museum building. WUFI was used to analyze the condensation potential for existing roof and wall assemblies and several iterations of proposed repair strategies.
- Hitchcock Hall, Dartmouth College, Hanover, NH – The consulting team reviewed past reports and material property test results, prepared a hygrothermal model and used the model to predict the performance of proposed retrofit options. The architectural drawings were also reviewed and rain water management and window installation details were developed.
- OAA Whole Building Air Barrier Testing, Toronto ON – Assisted whole building airtightness testing to assess the success of retrofit activities that had been undertaken as part of a larger project to achieve net-zero performance. Testing was performed in front of a live audience as a unique educational event.

Publications + Presentations

PAPERS + OTHER PUBLICATIONS

- Schumacher, Chris J. and Robert Lepage. "Building America Building Technologies Program: Moisture Control for Dense-Packed Roof Assemblies in Cold Climates: Final Measure Guideline." *Building America Program*, U.S. Department of Energy, Oak Ridge, TN, November 2012.
- Straube, John F., K. Ueno, and Chris J. Schumacher. "Measure Guideline: Internal Insulation of Masonry Walls", July 1, 2012.
- "Building America Building Technologies Program High Impact Project: Support of Standards Development: Dense-pack Airflow Resistance." *Building America Program*, U.S. Department of Energy, Oak Ridge, TN, November 2011.
- Lstiburek, J. and Schumacher, C.J. "Research Report 1110: Hygrothermal Analysis of California Attics." Building Science Corporation, Somerville, MA, October 2011.
- Schumacher, Chris J., Straube, J., Mensinga, P. "Assessing the Freeze-Thaw Resistance of Brick Masonry Units for Retrofit Insulation Projects." Presented at Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference, Clearwater, FL, December 2010.
- Schumacher, Chris J., et. al., "Adhered Veneers and Inward Vapor Drives: Significance, Problems and Solutions" *Journal of Building Enclosure Design* (Summer 2009).
- Straube, John F., Chris J. Schumacher, Jonathan Smegal, and M. Jablonka. "Adhered Veneers and Inward Vapor Drives: Significance, Problems, and Solutions." Presented at Canadian Conference on Building Science and Technology, Montreal, QC, 2009.
- Schumacher, Chris J., Reeves, E. "Field Performance of an Unvented Cathedral Ceiling (UCC) in Vancouver." Presented at Thermal Performance of the Exterior Envelopes of Whole Buildings X International Conference, Clearwater, December 2007.
- Ueno, K., Chris J. Schumacher, John F. Straube. "Field Monitoring and Hygrothermal Modeling of Interior Basement Insulation Systems." Thermal Performance of the Exterior Envelopes of Whole Buildings X International Conference, Clearwater, December 2007.
- Straube.J F., and Schumacher C.J., "Interior Insulation Retrofits of Load-Bearing Masonry Walls in Cold Climates." *Journal of Green Building* Vol. 2, No. 2 (Spring 2007): 42-50.
- Straube, John F., and Chris J. Schumacher. "Assessing the Durability Impacts of Energy Efficient Enclosure Upgrades using Hygrothermal Modeling." *Journal of the Intl. Assoc. for Science and Technology of Building Maintenance and Monuments Preservation* Vol 2 (2006).

RDH BUILDING SCIENCE

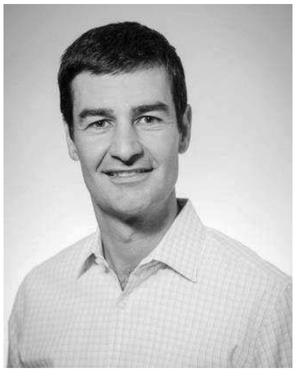
Chris Schumacher | M.A.Sc.

Principal, Senior Building Science Specialist

PRESENTATIONS + SPEAKING ENGAGEMENTS

- Schumacher, Chris J. and D. Ober. “Thermal Metric: the End is Near.” Presented at 17th Westford Symposium, Westford, MA, August 2013.
- Schumacher, Chris J. and Aaron Grin. “Thermal Metric Project: A Year of Progress.” Presented at 16th Westford Symposium, Westford, MA, August 2012.
- “Building Science.” Presented at Remodeling Industry Association Building Science Seminar, June 2012.
- “When Walls Work and When They Don’t.” Presented at NESEA BuildingEnergy12, Boston, MA, March 2012.
- “Thermal Metric Project.” Presented at 15th Westford Symposium, Westford, MA, August 2011.
- Schumacher, Chris J., John Straube and P. Mensinga. “Assessing the Freeze-thaw Resistance of Brick Masonry Units for Retrofit Insulation Projects.” Presented at Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference, Clearwater, FL, December 2010.
- “Field Measurements of Moisture in Building Materials and Assemblies”, Presented at BEST2, Portland, OR, April 2010.
- “When R-Value Doesn’t Measure Up.” Presented at NESEA BuildingEnergy10, Boston, MA. March 2010. Also presented at a workshop, Wyandotte, MI, February 2011.

RDH BUILDING SCIENCE



Robert Bombino | MS, PE

President, Senior Building Science Specialist

Robert Bombino has focused his entire career consulting on the building enclosure. He is regarded as an industry leader in evaluating thermal and hygrothermal (heat, air, and moisture) performance of building enclosure systems, and he has extensive experience with a variety of materials used across the United States and Canada. Robert leads building enclosure projects for buildings of all types: new and existing; high- and low-rise; and commercial, institutional, and residential.

Expertise + Experience

Robert's experience includes steep- and low-slope roofing systems, wall cladding (masonry, EIFS, concrete, metal panel, stucco, siding, etc.), windows, glazing, and glass/metal curtain walls as well as below-grade and plaza waterproofing systems. He investigates, designs, and reviews construction of enclosure restoration projects for existing buildings and also provides design and construction review on new construction projects. In addition, he provides expert testimony and litigation support for construction defect claims.

Robert's education, experience, and proficiency with state-of-the-art analysis software enable him to perform advanced thermal and hygrothermal analyses. This expertise is particularly relevant when dealing with specialty buildings with sustained high indoor humidity such as museums and natatoriums.

Robert is a shareholder and Managing Principal of RDH and is committed to the success of RDH projects.

Education

M.S., Architectural Engineering, Pennsylvania State University, University Park

B.A.Sc., Honors Co-op, Civil Engineering, University of Waterloo, Waterloo, ON, Canada

Memberships + Awards

Registered Professional Engineer (MA, WA)

American Society for Testing & Materials (ASTM)

ASTM, Committee C16, D08, and E06 Voting Member

American Society of Heating, Refrigerating, and

Air-Conditioning Engineers (ASHRAE) Technical Committee 4.4, Past Voting Member

Typical Projects

NEWCONSTRUCTION

Robert has provided building enclosure design review services for several new construction projects. Some examples include:

- → Amazon Blocks 26, 32, 34, 35, 44, 45 and 52, Seattle, WA
- → Bravern III and IV, Bellevue, WA – Two 33-story residential towers constructed over a 4-story retail base
- → Banner Thunderbird and Ironwood Medical Centers, Phoenix, AZ
- → Aspira, Seattle, WA – 38-story residential tower
- → Gallery, Seattle, WA – 13-story residential tower
- → Health and Science Center, Northwest University, Kirkland, WA
- → Enso, Seattle, WA –19-story residential tower and 12-story commercial tower, both rising from a 6-story base
- → Avalon Towers, Bellevue, WA – 2-tower residential project of 15 and 24 stories
- → Pharmacy/Biology Building, University of Connecticut, Storrs, CT

Bravern III and IV, Bellevue, WA

RDH BUILDING SCIENCE

Robert Bombino | MA, PE

President, Senior Building Science Specialist

CONDITION ASSESSMENTS

Robert conducts investigations and condition assessments for wall cladding (stucco, EIFS, masonry), plaza and below-grade waterproofing, windows, and glass/metal curtain walls, including:

- → Washington Square, Bellevue, WA
- → Labor & Industries Head Office, Tumwater, WA
- → Rieke Science Center, Pacific Lutheran University, Tacoma, WA
- → Lake Placid Lodge, Whistler, BC
- → Santa Cruz County Health Services Building, CA
- → Harbor Towers, San Diego, CA
- → Kirby Place, Houston, TX
- → Highland District Hospital, Hillsboro, OH
- → Law School Library, University of Connecticut, Hartford, CT

Labor and Industries Head Office, Tumwater, WA

LITIGATION SUPPORT

Robert regularly provides expert testimony and litigation support related to building enclosure performance problems. He is recognized as objective and provides services for plaintiff and defendant clients as well as acting as a neutral expert. Some examples include:

- → 2200 Westlake, Seattle, WA – Defense, Developer
- → 1521 Second Avenue, Seattle, WA – Defense, Developer
- → Gold Pointe, Tacoma, WA – Defense, Developer
- → Tidewater Cove, Vancouver, WA – Plaintiff, HOA
- → Mira, Kirkland, WA – Neutral Expert
- → 11th & Howell, Seattle, WA – Neutral Expert
- → Graystone at Altamont, Clackamas, OR – Plaintiff, HOA
- → Montere, Sammamish, WA – Defense, Developer
- → Woodlands, Everett, WA – Defense, Developer

REHABILITATION + CONSTRUCTION REVIEW

Robert provides building enclosure rehabilitation and renovation design and construction field review of cladding, fenestration, plaza waterproofing, and roofing. Some examples include:

- → 2200 Westlake, Seattle, WA
- → Graystone at Altamont, Clackamas County, OR
- → College Inn, Oregon State U., Corvallis, OR
- → Hotel Alder, Portland, OR
- → Cadillac Hotel, Seattle, WA
- → Gant Science Complex, U. of Connecticut, Storrs, CT
- → St. Agnes Church, Arlington, MA
- → Boston Public Library, Boston, MA
- → Christian Science Publishing House, Boston, MA
- → W. Zackin Natatorium, U. of Connecticut, Storrs, CT

Publications + Presentations

- → "Air Barriers: Energy Codes, Performance, and Applications" *Construction Specifications Institute* – Seattle and Spokane Chapter Meetings, January and April 2012; *Northwest Wall and Ceiling Bureau* – Portland andSeattle Chapter Meetings, October 2012.
- → "Moisture and Concrete: Moisture Physics, Testing, and Interpretation" *International Concrete Repair Institute* Seattle Chapter Meeting, February 2012.
- → "The Consultant's Perspective" *8th Annual Construction Defects: Update & Strategies* December 2011.
- → "Low-Energy Buildings: Enclosure Design" *Net Zero Workshop*, Tacoma, WA, October 2011.
- → "Air Barrier Commissioning of Large Buildings" *2011 BC Building Enclosure Council Conference and Annual General Meeting*, September 2011.
- → "Energy Consumption in High-Rise Residential Buildings" *SeaBEC Conference*, May 2011.
- → "Airtightness Within Buildings" *Association of Professional Engineers and Geoscientists of BC Conference*, February 2011.
- → "Windows, Fenestration, and Detailing" *Construction Specifications Institute* Seattle Chapter Meeting, January 2011.
- → Bombino, R. and Finch, G. "Reconsidering the Approach Toward Determining Overall Building Enclosure Thermal Performance for Code Compliance" *Thermal Performance of Exterior Envelopes of Whole Buildings XI,* Clearwater, FL, December 2010.

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Robert Bombino | MA, PE

President, Senior Building Science Specialist

- "High-Performance Building Enclosure Design" *Net Zero Workshop*, Tacoma, WA, October 2010.
- Finch, G., Hubbs, B., and Bombino, R. "Osmosis and Blistering Polyurethane Waterproofing Membranes" *12th Conference on Building Science & Technology*, Montreal, QC, March 2009.
- "Metal Roofing," *AIA It's in the Details – The Horizontal Plane*, Seattle, WA, November 2006.
- "Stumbling Blocks in Multiunit Residential Projects," *ASHRAE*, Quebec City, QC, June 2006.
- "Rainscreen Wall Systems: What, When, How," *Construction Specifications Institute*, Seattle, WA, April 2006.
- "Building Science and the Building Enclosure," *Washington Association of Building Officials (WABO) Conference*, Seattle, WA, April 2006.
- "Key Elements in Designing Wall Systems," *Portland Building Enclosure Council*, Portland, OR, February 2006.
- "The Art and Science of Flashing," ASHRAE, Chicago, IL, January 2006.
- Bombino, R. and Hubbs, B., "Impact of Architectural & HVAC Design & Occupants on Condensation Performance of Exterior Walls in Multiunit Residential Buildings" *10th Conference on Building Science & Technology*, Ottawa, ON, May 2005.
- "Lessons Learned - Building Enclosure Design Construction and Performance," *UW Continuing Professional Education Program*, Seattle, WA, March 1, 2005.
- Ricketts, D. and Bombino, R. "Study of Poured-in-Place Concrete Wall Performance in Coastal BC" *Canada Mortgage & Housing Corporation*, BC Homeowner Protection Office, 2004.
- Burnett, E.F.P. and Bombino, R., "Heat and Moisture Considerations with Steel Framing in Low-Rise Residential Construction" *Performance of Exterior Envelopes of Whole Buildings VIII Symposium,* Clearwater, FL, December 2–6, 2001.
- Bombino, R. and Burnett E.F.P., "Design Issues with Steel Stud–Framed Wall Systems" *Pennsylvania Housing Research Center*, University Park, PA, May 1999. Reprinted as "Weighing Thermal Design Strategies for Steel-Framed Homes (Parts 1 and 2)" *Energy Design Update,* December 1999 and January 2000.
- Bombino, R., "Hygrothermal Design Issues with Steel-Framed Enclosure Wall Systems," *Master's Thesis, Pennsylvania State University Department of Architectural Engineering*, University Park, PA, 1999.

Appendix B – RDH Rate Sheet

RDH BUILDING SCIENCE

Schedule "A" – Project Rates and Reimbursable Expenses

PROJECT RATES

Description	Project Rates ($/hr)
Senior Specialist	300
Specialist Senior Project Manager 2	270
Senior Project Manager 1	245
Senior Project Engineer Senior Project Architect Senior Project Designer / Consultant	220
Project Engineer Project Architect Project Designer / Consultant	195
Engineer Architect Designer / Consultant	170
Engineer (EIT) 2 Intern Architect (IA) 2 Technologist 4	135
Engineer (EIT) 1 Intern Architect (IA) 1 Technologist 3	125
Technologist 2 Coordinator Drafter 2	115
Technologist 1 Drafter	105
Assistant	85

PROJECT RATE ADJUSTMENT

RDH reviews rates across the firm on a periodic basis and Project Rates are subject to adjustment consistent with that periodic review. Project Rates may be increased by no more than 10% per year.

REIMBURSABLE EXPENSES AND LITIGATION SUPPORT

The *Client* agrees to pay direct expenses, grossed up by 10% to cover overhead, reasonably incurred by *RDH* in the performance of the services.

Equipment will be provided by *RDH* as required to perform the services and will be charged at rates established periodically and provided to the *Client* upon request.

Attendance at, and preparation for, court, mediation, deposition, discoveries, or hearings are at the above rates plus 50%.

Appendix C – List of Documents Reviewed

LIST OF DOCUMENTS REVIEWED		
TITLE/ DESCRIPTION	DATE	AUTHOR
COMPLAINT		
Complaint and Jury Demand (No. 2:18-CV-393)		BKC LLP
INDUSTRY DOCUMENTATION		
Bulletin PNW 257, "Potatoes Storage and Quality Maintenance in the Pacific Northwest"	Sept 1985	Pacific Northwest Cooperative Extension
Bulletin PNW 277, "Onion Storage Guidelines for Commercial Growers"	May 1985	Pacific Northwest Cooperative Extension
"Postharvest Cooling and Handling of Onions"	Sept 1992	NC State Extension
Bulletin EM2799, "Potato Storage and Ventilation"	Aug 1993	WSU Cooperative Extension
New England Vegetable and Fruit Conference: Postharvest & Storage Seminar: "Engineering Winter Storage Facilities for Vegetable Crops"	Dec 2011	Stephen Belyea (Maine Dept. of Agriculture, Food, and Rural Resources)
World Potato Congress, Workshop 1, "Storing Potatoes Perfectly"	May 2012	Olsen (University of Idaho) and Cunnington (AHDB Potato Council, UK)
"Control of Potato Storage Conditions for the Management of Post-harvest Losses due to Diseases"	May 2017	Canadian Horticultural Council
ASHRAE Systems and Equipment 2008 Chapter 20, "Fans"	2008	American Society of Heating, Refrigerating, and Air Conditioning Engineers
AMCA 201-02 (R2011), "Fans and Systems"	2011	Air Movement and Control Association International, Inc.
PROPOSALS AND CONTRACTS		
Equipment Summary – Sheet1.pdf (IVI000807)		IVI
GP 1 Lee 1 – 2012 Storage Proposal and documentation – Part 1.pdf (Proposal & Contract)		IVI
GP 1 Lee 1 – 2012 Storage Proposal and documentation – Part 2.pdf (Fan Strategies & Utility Incentives)		IVI
GP 1 Lee 1 – 2012 Storage Proposal and documentation – Part 3.pdf (Brochures)		IVI
J12-048BVR-AJ Ochoa Contract.pdf (Signed Contract)		IVI
J12-048BVR-AJ Ochoa.pdf (Proposal/Contract Drawings)		IVI

LIST OF DOCUMENTS REVIEWED (CONTINUED)		
TITLE/ DESCRIPTION	DATE	AUTHOR
PROPOSALS AND CONTRACTS (continued)		
GP 2 Lee 2 – 2015 Storage Proposal and documentation – Part 1.pdf (Proposal & Contract w/ Onion Storage Evaluation)		IVI
GP 2 Lee 2 – 2015 Storage Proposal and documentation – Part 2.pdf (Drawings)		IVI
GP 2 Lee 2 – 2015 Storage Proposal and documentation – Part 3.pdf (Brochures)		IVI
J15-039VR AJ OCHOA – CONTRACT AAAQ3713.pdf		IVI
J15-039VR AJ OCHOA – SIGNATURE PAGE-1.pdf		IVI
J15-039VR AJ Ochoa.pdf		IVI
DRAWINGS		
CBC TERRA GOLD PAGES 1-11.pdf		CBC
C15C0149_CombinedScan STAMPED CBC.pdf		CBC
IVI EMAIL RESPONSES FROM F. BUSHMAN		
F Bushman email – General info Storage Season 2015-2016	May 17, 2017 12:18 pm	F. Bushman, IVI
F Bushman email – “Terra Gold equipment lists and design criteria”	May 17, 2017 6:36 pm	F. Bushman, IVI
F Bushman email – “Terra Gold equipment lists and design criteria” Attachment: Terra Gold Storage Drawings and Equipment Lists	Attached May 17, 2017 6:36 pm	F. Bushman, IVI
F Bushman email – “How IVI computer panels generally operate and specific Centurion capabilities”	May 19, 2017 5:13 pm	F. Bushman, IVI
F Bushman email – “How IVI computer panels generally operate and specific Centurion capabilities” Attachment: Centurion Serios Potato, General User’s Guide	Attached May 19, 2017 5:13 pm	F. Bushman, IVI
F Bushman email – “How IVI computer panels generally operate and specific Centurion capabilities” Attachment: Air Circulation Diagrams	Attached May 19, 2017 5:13 pm	F. Bushman, IVI
END OF LIST		

Appendix D – RDH Airflow Measurements

21641.000 TerraGold Farms - Fan Pressure and Flow Measurements (RDH, Oct 2019)

Test Number	SHORT description	Current Storage	No. Fans	Measured fan pressure (Pa)	Measured fan pressure (in.H20)	Total Flow (CFM)	CFM/ton potatoes (assumes 9000 tons)	CFM/ton onions (assumes 4000 tons)	CFM/ton onions (assumes 5200 tons)
Test 1	GP1, Bay 3, recirculation @ 50%, Extra Louvers masked	Empty	4	88	0.35	71,256	7.9	17.8	
Test 2	GP1, Bay 3, recirculation @ 100%, Extra Louvers masked	Empty	4	333	1.34	151,892	16.9	38.0	
Test 3	GP1, Bay 3, fresh air @ 50%, Extra louvers masked	Empty	4	109	0.44	59,247	6.6	14.8	
Test 4	GP1, Bay 3, fresh air @ 100%, Extra Louvers masked	Empty	4	359	1.44	138,956	15.4	34.7	
Test 5	GP1, Bay 3, fresh air @ 50%, Extra Louvers open	Empty	4	101	0.40	63,542	7.1	15.9	
Test 6	GP1, Bay 3, fresh air @ 100%, Extra Louvers open	Empty	4	332	1.33	144,455	16.1	36.1	
Test 7	GP1, Bay 3, Influence Test, fresh air @ 100%, Extra Louvers open Bay 4 Fans ON	Empty	4	-	-	142,641	15.8	35.7	
Test 8	GP1, Bay 1, recirculation @ 50%, Extra Louvers masked, Humidicell Water ON	Potatoes	4	100	0.40	68,573	7.6	17.1	
Test 9	GP1, Bay 1, recirculation @ 100%, Extra Louvers masked, Humidicell Water ON	Potatoes	4	378	1.52	147,327	16.4	36.8	
Test 9B	GP1, Bay 1, recirculation @ 100%, Extra Louvers masked, Humidicell water OFF	Potatoes	4	361	1.45	160,681	17.9	40.2	
Test 10	GP1, Bay 1, fresh air @ 50%, Extra Louvers masked	Potatoes	4	116	0.47	61,677	6.9	15.4	
Test 11	GP1, Bay 1, fresh air @ 100%, Extra Louvers masked	Potatoes	4	403	1.62	144,022	16.0	36.0	
Test 12	GP1, Bay 1, fresh air @ 50%, Extra Louvers open	Potatoes	4	105	0.42	66,183	7.4	16.5	
Test 13	GP1, Bay 1, fresh air @ 100%, Extra Louvers open	Potatoes	4	365	1.47	162,026	18.0	40.5	
Test 14	GP2, Bay 5, recirculation @ 50%, Extra Louvers masked	Onions	5	108	0.43	91,132	10.1		17.5
Test 15	GP2, Bay 5, recirculation @ 100%, Extra Louvers masked	Onions	5	404	1.62	205,066	22.8		39.4
Test 16	GP2, Bay 5, fresh air @ 50%, Extra Louvers masked	Onions	5	118	0.47	77,703	8.6		14.9
Test 17	GP2, Bay 5, fresh air @ 100%, Extra Louvers masked	Onions	5	411	1.65	187,725	20.9		36.1
Test 18	GP2, Bay 5, fresh air @ 50%, Extra Louvers open	Onions	5	111	0.45	84,170	9.4		16.2
Test 19	GP2, Bay 5, fresh air @ 100%, Extra Louvers open	Onions	5	381	1.53	197,070	21.9		37.9

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 1	10/7/2019	17:40:00 PM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Recirculation @ 50%, Extra Louvers Masked

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	
			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
1.16	1.14	1.17	1.32	1.05	0.86	1.23	0.73	4
1.08	1.15	1.24	1.24	1.06	0.79	1.02	0.77	3
1.18	1.33	1.02	1.23	1.11	1.33	0.89	1.25	2
1.09	1.09	0.92	1.07	0.85	0.92	0.84	1.17	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
4.64	9.12	9.36	9.24	7.35	6.88	9.84	2.92	4
8.40	17.88	19.28	16.87	14.42	12.29	15.86	5.99	3
9.18	20.68	15.86	16.74	15.10	20.68	13.84	9.72	2
4.36	8.72	7.36	7.49	5.95	7.36	6.72	4.68	1

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor 1.05
Area Weighted Average (m/s) 1.14

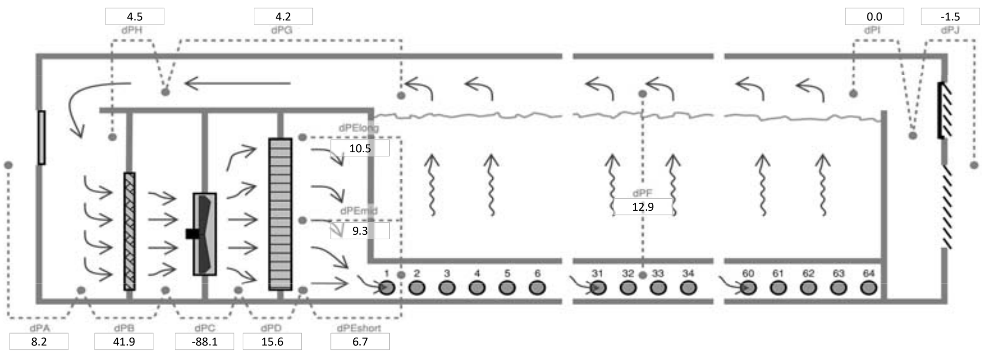
A	B	C	D	E	F	G	H	
4.87	9.58	9.83	9.70	7.72	7.22	10.33	3.07	4
8.82	18.78	20.25	17.72	15.15	12.90	16.66	6.29	3
9.64	21.72	16.66	17.58	15.86	21.72	14.53	10.21	2
4.58	9.16	7.73	7.87	6.25	7.73	7.06	4.91	1

SUMMARY	
Total Flow (CFM)	**71,256**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**7.92**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**17.81**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/7/2019

Test No.	1
Bay No.	3
Stored	Empty
No. Fans	4
Flow Mode	Recirc
Fan Speed	50%
Extra Louvers	Masked

Staff: C. Schumacher
D. Jones
M. Rumeo
X. (Ray) Lu



Logger Start	10/7/2019 17:29	3
Logger End	10/7/2019 18:22	3069
Analyse Start	10/7/2019 17:40	651
Analyse End	10/7/2019 18:20	2928

		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	8.2	0.033	1.8	0.007	651	2928
Thru Cooling Coil	delta PB	41.9	0.168	1.1	0.005	651	2928
Thru Fan Bank	delta PC	-88.1	-0.354	1.4	0.006	651	2928
Thru Humidicell Deck	delta PD	15.6	0.062	1.4	0.005	651	2928
Into Sup Plenum (Short)	delta PE1	6.7	0.027	1.9	0.008	651	2928
Into Sup Plenum (Middle)	delta PE2	9.3	0.037	0.9	0.004	651	2928
Into Sup Plenum (Long)	delta PE3	10.5	0.042	1.0	0.004	651	2928
Sup to Exh Plenum	delta PF	12.9	0.052	0.4	0.001	651	2928
Exh Plenum to Return	delta PG	4.2	0.017	0.4	0.002	651	2928
Thru Return Damper	delta PH	4.5	0.018	1.2	0.005	651	2928
Exh Plenum to Exh Louvers	delta PI	0.0	0.000	0.1	0.001	651	2928
Thru Exhaust Louvers	delta PJ	-1.5	-0.006	1.9	0.008	651	2928

Total Flow (CFM)	71,255.61
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	7.92

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 2	10/8/2019	8:40 AM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Recirculation @ 100%, Extra Louvers Masked

AREA (sq.ft.)

				A	B	C	D	E	F	G	H	
				2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2		4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89		7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89		7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2		4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft		A	B	C	D	E	F	G	H	

VELOCITY (m/s)

	A	B	C	D	E	F	G	H
4	2.64	2.69	2.61	2.78	2.32	1.69	2.48	1.53
3	2.31	2.51	2.62	2.19	2.31	1.65	2.13	1.49
2	2.47	2.93	2.29	3.09	2.04	2.75	1.89	2.93
1	2.44	2.32	2.04	2.19	1.71	2.15	1.71	2.51

AREA-WEIGHTED VELOCITY (m/s*ft2)

	A	B	C	D	E	F	G	H
4	10.56	21.52	20.88	19.46	16.24	13.52	19.84	6.12
3	17.96	39.04	40.75	29.80	31.43	25.66	33.13	11.59
2	19.21	45.57	35.61	42.05	27.76	42.77	29.39	22.78
1	9.76	18.56	16.32	15.33	11.97	17.20	13.68	10.04

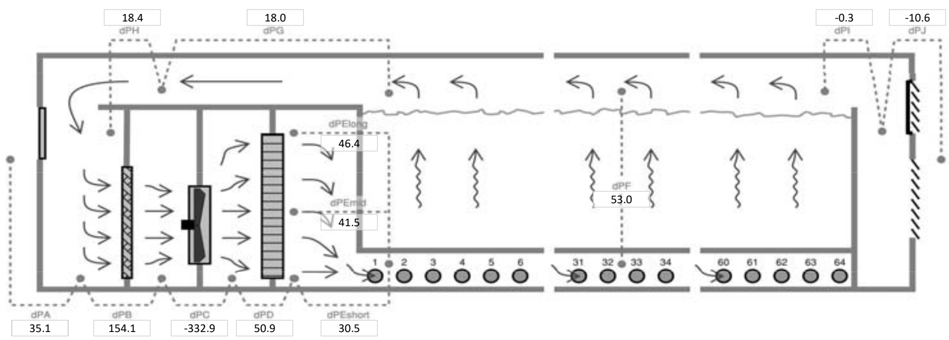
PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

			A	B	C	D	E	F	G	H	
Velocity Correction Factor	1.05		11.08	22.58	21.91	20.42	17.04	14.19	20.82	6.42	4
Area Weighted Average (m/s)	2.43		18.85	40.96	42.76	31.27	32.99	26.93	34.76	12.16	3
			20.16	47.82	37.37	44.12	29.13	44.88	30.84	23.91	2
			10.24	19.48	17.13	16.09	12.56	18.05	14.36	10.54	1

SUMMARY	
Total Flow (CFM)	**151,892**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**16.88**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**37.97**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	2	
Bay No.	3	
Stored	Empty	
No. Fans	4	
Flow Mode	Recirc	
Fan Speed	100%	
Extra Louvers	Masked	
Staff	C. Schumacher	
	D. Jones	
	M. Rumeo	
	X. (Ray) Lu	
Logger Start	10/8/2019 7:56	3
Logger End	10/8/2019 8:28	1896
Analyse Start	10/8/2019 8:00	204
Analyse End	10/8/2019 8:15	1090



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	35.1	0.141	4.9	0.020	204	1090
Thru Cooling Coil	delta PB	154.1	0.619	4.3	0.017	204	1090
Thru Fan Bank	delta PC	-332.9	-1.337	3.7	0.015	204	1090
Thru Humidicell Deck	delta PD	50.9	0.204	3.5	0.014	204	1090
Into Sup Plenum (Short)	delta PE1	30.5	0.122	2.7	0.011	204	1090
Into Sup Plenum (Middle)	delta PE2	41.5	0.167	3.0	0.012	204	1090
Into Sup Plenum (Long)	delta PE3	46.4	0.186	3.2	0.013	204	1090
Sup to Exh Plenum	delta PF	53.0	0.213	1.3	0.005	204	1090
Exh Plenum to Return	delta PG	18.0	0.072	1.7	0.007	204	1090
Thru Return Damper	delta PH	18.4	0.074	4.6	0.018	204	1090
Exh Plenum to Exh Louvers	delta PI	-0.3	-0.001	0.4	0.002	204	1090
Thru Exhaust Louvers	delta PJ	-10.6	-0.043	6.7	0.027	204	1090

Total Flow (CFM)	151,892.00
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	16.88

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 3	10/8/2019	9:10 AM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Fresh air @ 50%, Extra Louvers masked

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	
			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
0.83	0.96	1.01	1.05	0.76	0.67	0.97	0.60	4
0.83	0.97	0.95	0.95	0.88	0.72	0.95	0.67	3
0.82	1.16	1.03	1.03	1.00	1.02	0.78	0.98	2
0.87	0.85	0.76	0.79	0.79	0.86	0.73	0.90	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
3.32	7.68	8.08	7.35	5.32	5.36	7.76	2.40	4
6.45	15.09	14.77	12.93	11.98	11.20	14.77	5.21	3
6.38	18.04	16.02	14.02	13.61	15.86	12.13	7.62	2
3.48	6.80	6.08	5.53	5.53	6.88	5.84	3.60	1

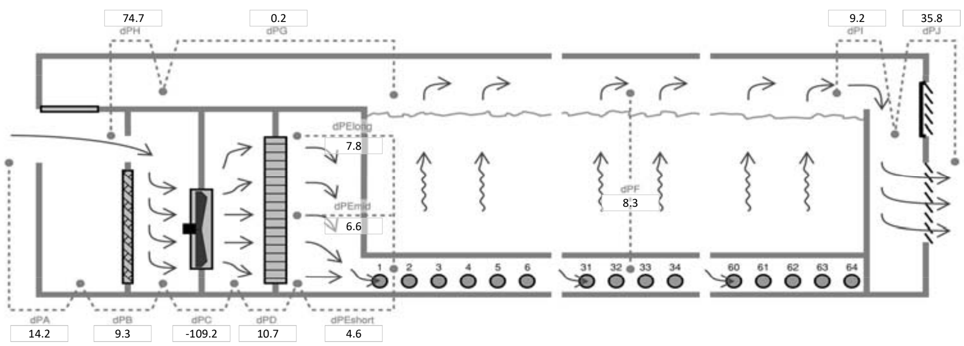
PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

		A	B	C	D	E	F	G	H	
Velocity Correction Factor	1.05	3.48	8.05	8.47	7.71	5.58	5.62	8.14	2.52	4
Area Weighted Average (m/s)	0.95	6.77	15.82	15.49	13.56	12.56	11.74	15.49	5.46	3
		6.69	18.92	16.80	14.70	14.27	16.64	12.72	7.99	2
		3.65	7.13	6.38	5.80	5.80	7.21	6.12	3.78	1

SUMMARY	
Total Flow (CFM)	**59,247**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**6.58**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**14.81**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	3	
Bay No.	3	
Stored	Empty	
No. Fans	4	
Flow Mode	Fresh	
Fan Speed	50%	
Extra Louvers	Masked	
Staff	C. Schumacher D. Jones M. Rumeo X. (Ray) Lu	
Logger Start	10/8/2019 9:04	3
Logger End	10/8/2019 9:34	254
Analyse Start	10/8/2019 9:10	49
Analyse End	10/8/2019 9:30	218



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	14.2	0.057	2.0	0.008	49	218
Thru Cooling Coil	delta PB	9.3	0.038	0.8	0.003	331	1513
Thru Fan Bank	delta PC	-109.2	-0.439	3.0	0.012	331	1513
Thru Humidicell Deck	delta PD	10.7	0.043	1.4	0.006	331	1513
Into Sup Plenum (Short)	delta PE1	4.6	0.018	0.8	0.003	331	1513
Into Sup Plenum (Middle)	delta PE2	6.6	0.027	1.5	0.006	331	1513
Into Sup Plenum (Long)	delta PE3	7.8	0.031	1.2	0.005	331	1513
Sup to Exh Plenum	delta PF	8.3	0.033	0.6	0.002	331	1513
Exh Plenum to Return	delta PG	0.2	0.001	0.7	0.003	331	1513
Thru Return Damper	delta PH	74.7	0.300	4.9	0.020	331	1513
Exh Plenum to Exh Louvers	delta PI	9.2	0.037	1.4	0.005	331	1513
Thru Exhaust Louvers	delta PJ	35.8	0.144	4.4	0.018	331	1513

Total Flow (CFM)	59,247.29
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	6.58

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 4	10/8/2019	9:37 AM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Fresh air @ 100%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

2.25	2.34	2.46	2.74	2.04	1.68	2.35	1.34	4
2.23	2.36	2.30	2.19	2.04	1.67	1.70	1.32	3
2.56	2.66	2.31	2.75	2.03	2.52	1.70	1.91	2
2.32	2.00	1.81	1.93	1.64	1.97	1.63	2.13	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

9.00	18.72	19.68	19.18	14.28	13.44	18.80	5.36	4
17.34	36.70	35.77	29.80	27.76	25.97	26.44	10.26	3
19.91	41.37	35.93	37.42	27.62	39.19	26.44	14.85	2
9.28	16.00	14.48	13.51	11.48	15.76	13.04	8.52	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.05	9.44	19.63	20.64	20.11	14.97	14.09	19.71	5.62	4
Area Weighted Average (m/s)	2.22	18.18	38.49	37.51	31.25	29.11	27.24	27.73	10.76	3
		20.88	43.38	37.67	39.24	28.97	41.10	27.73	15.57	2
		9.73	16.78	15.18	14.17	12.04	16.53	13.67	8.93	1
		A	B	C	D	E	F	G	H	

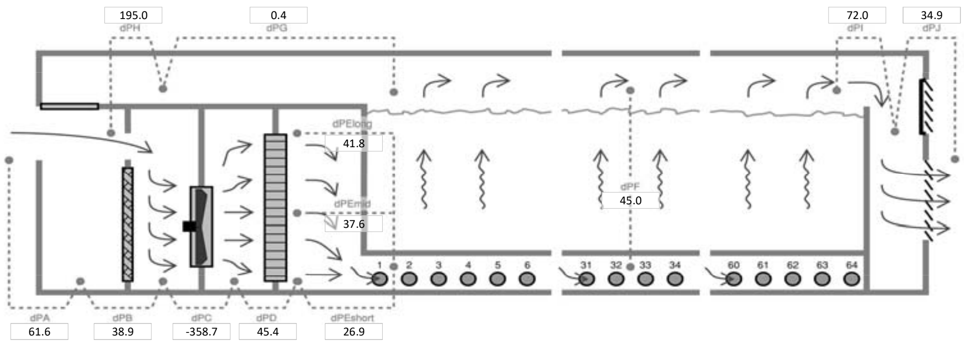
SUMMARY	
Total Flow (CFM)	**138,956**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**15.44**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**34.74**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	4
Bay No.	3
Stored	Empty
No. Fans	4
Flow Mode	Fresh
Fan Speed	100%
Extra Louvers	Masked

Staff: C. Schumacher, D. Jones, M. Rumeo, X. (Ray) Lu

Logger Start	10/8/2019 9:34	3
Logger End	10/8/2019 9:58	1374
Analyse Start	10/8/2019 9:37	126
Analyse End	10/8/2019 9:47	717



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	61.6	0.247	3.2	0.013	126	717
Thru Cooling Coil	delta PB	38.9	0.156	2.3	0.009	126	717
Thru Fan Bank	delta PC	-358.7	-1.441	5.5	0.022	126	717
Thru Humidicell Deck	delta PD	45.4	0.182	4.2	0.017	126	717
Into Sup Plenum (Short)	delta PE1	26.9	0.108	2.3	0.009	126	717
Into Sup Plenum (Middle)	delta PE2	37.6	0.151	2.6	0.011	126	717
Into Sup Plenum (Long)	delta PE3	41.8	0.168	2.5	0.010	126	717
Sup to Exh Plenum	delta PF	45.0	0.181	1.2	0.005	126	717
Exh Plenum to Return	delta PG	0.4	0.001	0.6	0.002	126	717
Thru Return Damper	delta PH	195.0	0.783	4.9	0.020	126	717
Exh Plenum to Exh Louvers	delta PI	72.0	0.289	2.6	0.010	126	717
Thru Exhaust Louvers	delta PJ	34.9	0.140	3.4	0.014	126	717

Total Flow (CFM)	138,955.55
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	15.44

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 5	10/8/2019	11:27 AM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Fresh air @ 50%, Extra Louvers open

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

1.08	1.05	1.05	1.10	0.85	0.79	1.03	0.68	4
0.95	1.03	1.03	1.01	0.91	0.87	0.99	0.69	3
1.05	1.24	1.05	1.23	0.88	1.26	0.74	0.97	2
1.02	0.96	0.71	0.90	0.72	0.82	0.73	0.92	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

4.32	8.40	8.40	7.70	5.95	6.32	8.24	2.72	4
7.39	16.02	16.02	13.74	12.38	13.53	15.40	5.37	3
8.16	19.28	16.33	16.74	11.98	19.60	11.51	7.54	2
4.08	7.68	5.68	6.30	5.04	6.56	5.84	3.68	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.05	4.53	8.81	8.81	8.07	6.24	6.63	8.64	2.85	4
Area Weighted Average (m/s)	1.02	7.75	16.80	16.80	14.41	12.99	14.19	16.15	5.63	3
		8.56	20.22	17.12	17.55	12.56	20.55	12.07	7.91	2
		4.28	8.05	5.96	6.61	5.29	6.88	6.12	3.86	1
		A	B	C	D	E	F	G	H	

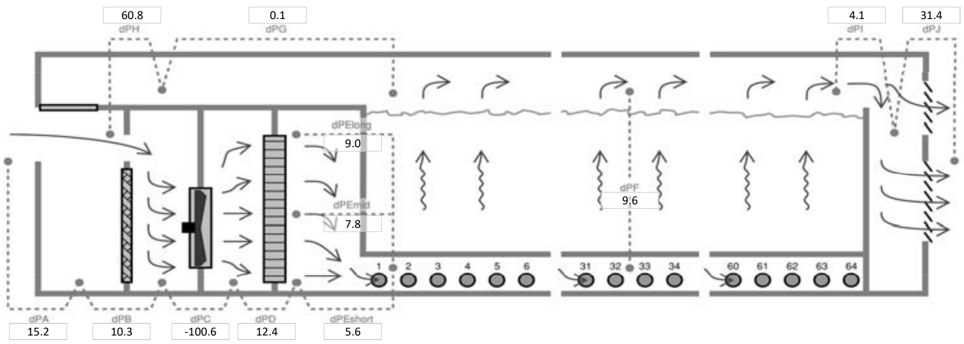
SUMMARY	
Total Flow (CFM)	**63,542**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**7.06**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**15.89**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	5
Bay No.	3
Stored	Empty
No. Fans	4
Flow Mode	Fresh
Fan Speed	50%
Extra Louvers	Open

Staff: C. Schumacher, D. Jones, M. Rumeo, X. (Ray) Lu

Logger Start	10/8/2019 11:17	3
Logger End	10/8/2019 11:58	2435
Analyse Start	10/8/2019 11:27	585
Analyse End	10/8/2019 11:57	2357



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	15.2	0.061	1.5	0.006	585	2357
Thru Cooling Coil	delta PB	10.3	0.041	0.8	0.003	585	2357
Thru Fan Bank	delta PC	-100.6	-0.404	3.3	0.013	585	2357
Thru Humidicell Deck	delta PD	12.4	0.050	1.4	0.005	585	2357
Into Sup Plenum (Short)	delta PE1	5.6	0.022	1.8	0.007	585	2357
Into Sup Plenum (Middle)	delta PE2	7.8	0.031	1.4	0.006	585	2357
Into Sup Plenum (Long)	delta PE3	9.0	0.036	1.1	0.004	585	2357
Sup to Exh Plenum	delta PF	9.6	0.039	0.6	0.002	585	2357
Exh Plenum to Return	delta PG	0.1	0.000	0.4	0.002	585	2357
Thru Return Damper	delta PH	60.8	0.244	4.9	0.020	585	2357
Exh Plenum to Exh Louvers	delta PI	4.1	0.017	0.9	0.003	585	2357
Thru Exhaust Louvers	delta PJ	31.4	0.126	3.2	0.013	585	2357

Total Flow (CFM)	63,542.11
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	7.06

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 6	10/8/2019	12:10 PM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Fresh air @ 100%, Extra Louvers open

AREA (sq.ft.)

Total Height (ft) 11.78
Total Width (ft) 27.00
Total Area (sf) 317.95

		2	4	4	3.5	3.5	4	4	2	ft
	2	4	8	8	7	7	8	8	4	4
	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
	2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
	ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

2.40	2.70	2.37	2.78	2.04	1.59	2.45	1.46	4
2.32	2.52	2.42	2.56	2.06	1.53	1.90	1.50	3
2.47	2.72	2.42	2.42	2.23	2.87	1.72	2.25	2
2.17	2.04	1.74	2.13	1.66	2.07	1.60	2.26	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

9.60	21.60	18.96	19.46	14.28	12.72	19.60	5.84	4
18.04	39.19	37.64	34.84	28.03	23.79	29.55	11.66	3
19.21	42.30	37.64	32.93	30.35	44.63	26.75	17.50	2
8.68	16.32	13.92	14.91	11.62	16.56	12.80	9.04	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor 1.05
Area Weighted Average (m/s) 2.31

10.07	22.65	19.88	20.41	14.97	13.34	20.55	6.12	4
18.92	41.10	39.47	36.53	29.40	24.95	30.99	12.23	3
20.14	44.36	39.47	34.53	31.82	46.81	28.05	18.35	2
9.10	17.11	14.60	15.64	12.19	17.37	13.42	9.48	1
A	B	C	D	E	F	G	H	

SUMMARY	
Total Flow (CFM)	**144,455**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**16.05**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**36.11**

Terra Gold Othello Storage - Airflow Investigation
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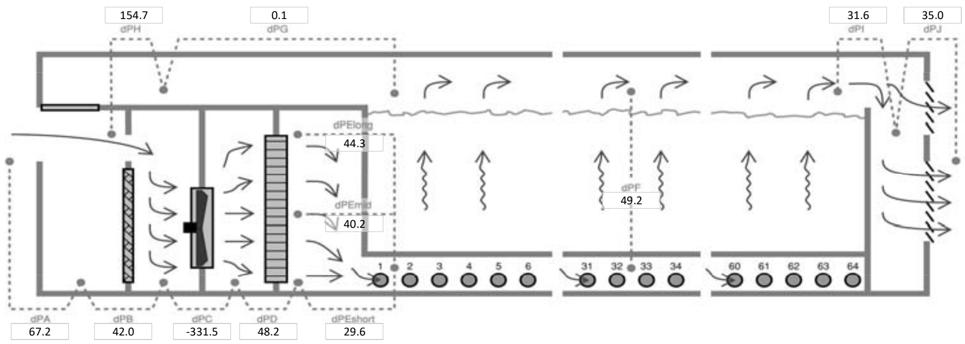
Test No.	6
Bay No.	3
Stored	Empty
No. Fans	4
Flow Mode	Fresh
Fan Speed	100%
Extra Louvers	Open

Staff: C. Schumacher, D. Jones, M. Rumeo, X. (Ray) Lu

Logger Start	10/8/2019 12:07	3
Logger End	10/8/2019 12:56	2868
Analyse Start	10/8/2019 12:10	127
Analyse End	10/8/2019 12:50	2490



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	67.2	0.270	3.5	0.014	127	2490
Thru Cooling Coil	delta PB	42.0	0.169	2.8	0.011	127	2490
Thru Fan Bank	delta PC	-331.5	-1.331	6.3	0.025	127	2490
Thru Humidicell Deck	delta PD	48.2	0.194	4.4	0.018	127	2490
Into Sup Plenum (Short)	delta PE1	29.6	0.119	3.5	0.014	127	2490
Into Sup Plenum (Middle)	delta PE2	40.2	0.162	2.8	0.011	127	2490
Into Sup Plenum (Long)	delta PE3	44.3	0.178	3.5	0.014	127	2490
Sup to Exh Plenum	delta PF	49.2	0.198	1.6	0.006	127	2490
Exh Plenum to Return	delta PG	0.1	0.000	0.6	0.002	127	2490
Thru Return Damper	delta PH	154.7	0.621	6.3	0.025	127	2490
Exh Plenum to Exh Louvers	delta PI	31.6	0.127	2.6	0.010	127	2490
Thru Exhaust Louvers	delta PJ	35.0	0.141	3.4	0.014	127	2490

Total Flow (CFM)	144,454.98
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	16.05

GP1, Bay 3, Empty	ID	Date	Time	Staff present	Condition Description
	Test 7	10/8/2019	2:07 PM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Influence test, Fresh air @ 100%, Extra Louvers open

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

2.26	2.51	2.50	2.57	2.06	1.54	2.08	1.50	4
2.23	2.38	2.29	2.54	2.06	1.67	2.01	1.56	3
2.47	2.92	2.29	2.61	2.16	2.52	1.81	2.25	2
2.20	2.05	1.75	1.95	1.68	2.02	1.73	2.04	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

9.04	20.08	20.00	17.99	14.42	12.32	16.64	6.00	4
17.34	37.01	35.61	34.56	28.03	25.97	31.26	12.13	3
19.21	45.41	35.61	35.52	29.39	39.19	28.15	17.50	2
8.80	16.40	14.00	13.65	11.76	16.16	13.84	8.16	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.05	9.48	21.06	20.97	18.87	15.12	12.92	17.45	6.29	4
Area Weighted Average (m/s)	2.28	18.18	38.82	37.35	36.25	29.40	27.24	32.78	12.72	3
		20.14	47.62	37.35	37.25	30.82	41.10	29.52	18.35	2
		9.23	17.20	14.68	14.31	12.33	16.95	14.51	8.56	1
		A	B	C	D	E	F	G	H	

Note:
Tests 1-6 were done with fans shut off in the adjacent storage area, Bay 4. Test 7 was done with Bay 4 fans set to run at the same speed as Bay 3 fans.

SUMMARY	
Total Flow (CFM)	**142,641**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**15.85**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**35.66**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	7
Bay No.	3
Stored	
No. Fans	
Flow Mode	
Fan Speed	
Extra Louvers	Open

Staff C. Schumacher
D. Jones
M. Rumeo
X. (Ray) Lu

Logger Start	10/8/2019 14:08	3
Logger End	10/8/2019 14:37	1751
Analyse Start	10/8/2019 14:09	40
Analyse End	10/8/2019 14:31	1340

		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	69.9	0.281	12.7	0.051	40	1340
Thru Cooling Coil	delta PB	39.3	0.158	7.3	0.029	40	1340
Thru Fan Bank	delta PC	-341.3	-1.371	57.5	0.231	40	1340
Thru Humidicell Deck	delta PD	47.2	0.189	9.0	0.036	40	1340
Into Sup Plenum (Short)	delta PE1	29.3	0.118	6.4	0.026	40	1340
Into Sup Plenum (Middle)	delta PE2	38.9	0.156	7.2	0.029	40	1340
Into Sup Plenum (Long)	delta PE3	42.8	0.172	8.0	0.032	40	1340
Sup to Exh Plenum	delta PF	53.4	0.214	9.4	0.038	40	1340
Exh Plenum to Return	delta PG	0.2	0.001	0.6	0.002	40	1340
Thru Return Damper	delta PH	165.2	0.664	28.0	0.112	40	1340
Exh Plenum to Exh Louvers	delta PI	38.4	0.154	7.1	0.028	40	1340
Thru Exhaust Louvers	delta PJ	33.1	0.133	6.8	0.027	40	1340

Total Flow (CFM)	142,641.25
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	15.85

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 8	10/8/2019	7:07 PM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Recirculation @ 50%, Extra Louvers masked, Water ON

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	
			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
1.13	1.12	1.20	1.00	1.08	1.08	1.02	1.00	4
0.99	1.05	1.09	0.98	0.98	0.98	1.01	0.97	3
1.14	0.98	1.05	1.10	1.12	1.12	1.27	1.03	2
0.98	0.99	1.08	0.98	0.96	0.96	0.96	0.89	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
4.52	8.96	9.60	7.00	7.56	8.64	8.16	4.00	4
7.70	16.33	16.95	13.34	13.34	15.24	15.71	7.54	3
8.86	15.24	16.33	14.97	15.24	17.42	19.75	8.01	2
3.92	7.92	8.64	6.86	6.72	7.68	7.68	3.56	1

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor 1.05

Area Weighted Average (m/s) 1.10

A	B	C	D	E	F	G	H	
4.72	9.36	10.03	7.32	7.90	9.03	8.53	4.18	4
8.05	17.07	17.72	13.94	13.94	15.93	16.42	7.88	3
9.27	15.93	17.07	15.64	15.93	18.20	20.64	8.37	2
4.10	8.28	9.03	7.17	7.02	8.03	8.03	3.72	1

Note:
Test 8 (recirc, 50%, water on) and 9 (recirc, 100%, water on) were done with the water running over the Humidicell Deck. This makes measurement of airflow challenging due to droplets of water falling off the face of the cell deck material or splashing up from the collection trough. Test 9B (recirc, 100%) was done with water off. Water off results in higher airflows. Remaining tests completed with water off.

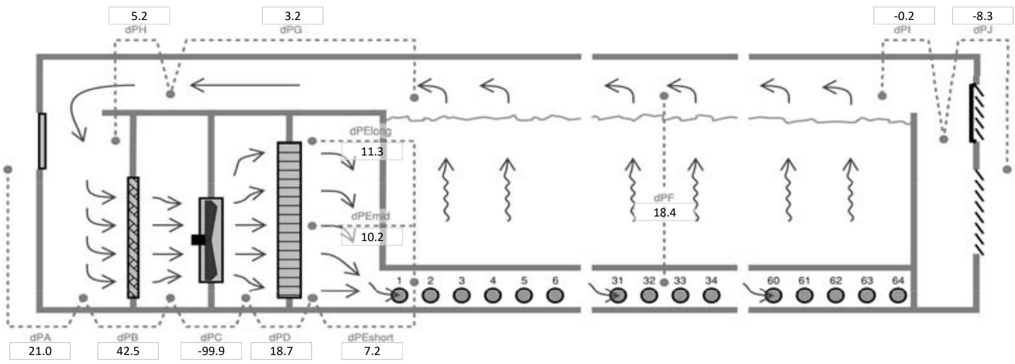
SUMMARY	
Total Flow (CFM)	**68,573**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**7.62**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**17.14**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	8
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Recirc
Fan Speed	50%
Extra Louvers	Masked

Staff: C. Schumacher
D. Jones
M. Rumeo
X. (Ray) Lu

Logger Start	10/8/2019 19:01	3
Logger End	10/8/2019 19:53	3101
Analyse Start	10/8/2019 19:07	329
Analyse End	10/8/2019 19:17	920



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	21.0	0.084	2.0	0.008	329	920
Thru Cooling Coil	delta PB	42.5	0.171	0.9	0.004	329	920
Thru Fan Bank	delta PC	-99.9	-0.401	1.2	0.005	329	920
Thru Humidicell Deck	delta PD	18.7	0.075	5.3	0.021	329	920
Into Sup Plenum (Short)	delta PE1	7.2	0.029	0.6	0.002	329	920
Into Sup Plenum (Middle)	delta PE2	10.2	0.041	5.1	0.021	329	920
Into Sup Plenum (Long)	delta PE3	11.3	0.046	1.2	0.005	329	920
Sup to Exh Plenum	delta PF	18.4	0.074	0.3	0.001	329	920
Exh Plenum to Return	delta PG	3.2	0.013	0.3	0.001	329	920
Thru Return Damper	delta PH	5.2	0.021	0.9	0.003	329	920
Exh Plenum to Exh Louvers	delta PI	-0.2	-0.001	0.3	0.001	329	920
Thru Exhaust Louvers	delta PJ	-8.3	-0.033	2.1	0.008	329	920

Total Flow (CFM)	68573.471
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	7.6192746

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 9	10/8/2019	20:55 PM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Recirculation @ 100%, Extra Louvers masked, Water ON

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

2.64	2.34	2.82	2.34	2.56	2.26	2.32	1.96	4
2.32	2.28	2.23	2.22	2.32	2.01	1.96	1.94	3
2.35	2.37	2.43	3.08	2.33	2.68	2.19	2.15	2
1.76	1.94	2.20	2.06	1.84	1.94	1.52	1.66	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

10.56	18.72	22.56	16.38	17.92	18.08	18.56	7.84	4
18.04	35.46	34.68	30.21	31.57	31.26	30.48	15.09	3
18.27	36.86	37.79	41.91	31.71	41.68	34.06	16.72	2
7.04	15.52	17.60	14.42	12.88	15.52	12.16	6.64	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.04	11.01	19.51	23.52	17.07	18.68	18.85	19.35	8.17	4
Area Weighted Average (m/s)	2.35	18.80	36.96	36.15	31.49	32.91	32.58	31.77	15.72	3
		19.05	38.42	39.39	43.69	33.05	43.45	35.50	17.43	2
		7.34	16.18	18.35	15.03	13.43	16.18	12.68	6.92	1
		A	B	C	D	E	F	G	H	

Note:
Test 8 (recirc, 50%, water on) and 9 (recirc, 100%, water on) were done with the water running over the Humidicell Deck. This makes measurement of airflow challenging due to droplets of water falling off the face of the cell deck material or splashing up from the collection trough. Test 9B (recirc, 100%) was done with water off. Water off results in higher airflows. Remaining tests completed with water off.

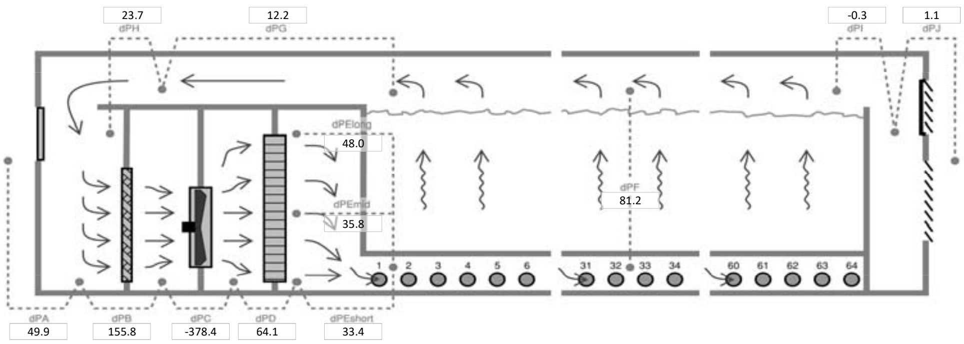
SUMMARY	
Total Flow (CFM)	**147,327**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**16.37**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**36.83**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/8/2019

Test No.	9
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Recirc
Fan Speed	100%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, X. (Ray) Lu

Logger Start	10/8/2019 20:25	3
Logger End	10/8/2019 20:57	1879
Analyse Start	10/8/2019 20:30	276
Analyse End	10/8/2019 20:50	1458



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	49.9	0.200	3.1	0.013	276	1458
Thru Cooling Coil	delta PB	155.8	0.626	2.9	0.012	276	1458
Thru Fan Bank	delta PC	-378.4	-1.520	3.4	0.014	276	1458
Thru Humidicell Deck	delta PD	64.1	0.257	3.7	0.015	276	1458
Into Sup Plenum (Short)	delta PE1	33.4	0.134	3.4	0.014	276	1458
Into Sup Plenum (Middle)	delta PE2	35.8	0.144	4.0	0.016	276	1458
Into Sup Plenum (Long)	delta PE3	48.0	0.193	3.8	0.015	276	1458
Sup to Exh Plenum	delta PF	81.2	0.326	0.9	0.003	276	1458
Exh Plenum to Return	delta PG	12.2	0.049	1.2	0.005	276	1458
Thru Return Damper	delta PH	23.7	0.095	3.3	0.013	276	1458
Exh Plenum to Exh Louvers	delta PI	-0.3	-0.001	0.2	0.001	276	1458
Thru Exhaust Louvers	delta PJ	1.1	0.004	2.9	0.012	276	1458

Total Flow (CFM)	147,327.14
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	16.37

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 9B	10/9/2019	8:30 AM	C. Schumacher, M. Rumeo, D. Jones, X. Lu	Recirculation @ 50%, Extra Louvers masked, Water OFF

AREA (sq.ft.)

		ft	A	B	C	D	E	F	G	H	
			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
2.96	2.64	2.95	2.43	2.78	2.42	2.53	1.91	4
2.35	2.34	2.60	2.25	2.56	2.19	2.31	2.06	3
2.57	2.49	2.65	3.43	2.50	2.78	2.40	2.43	2
2.38	2.40	2.66	2.28	2.33	2.20	2.16	1.90	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
11.84	21.12	23.60	17.01	19.46	19.36	20.24	7.64	4
18.27	36.39	40.44	30.62	34.84	34.06	35.93	16.02	3
19.98	38.72	41.21	46.68	34.02	43.23	37.33	18.90	2
9.52	19.20	21.28	15.96	16.31	17.60	17.28	7.60	1

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor 1.03
Area Weighted Average (m/s) 2.57

A	B	C	D	E	F	G	H	
12.21	21.78	24.34	17.54	20.07	19.97	20.87	7.88	4
18.85	37.53	41.70	31.58	35.93	35.13	37.05	16.52	3
20.61	39.94	42.51	48.14	35.09	44.59	38.50	19.49	2
9.82	19.80	21.95	16.46	16.82	18.15	17.82	7.84	1

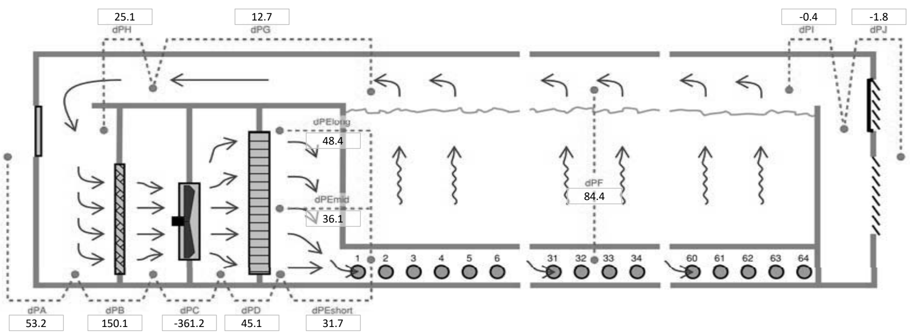
Note:
Test 8 (recirc, 50%, water on) and 9 (recirc, 100%, water on) were done with the water running over the Humidicell Deck. This makes measurement of airflow challenging due to droplets of water falling off the face of the cell deck material or splashing up from the collection trough. Test 9B (recirc, 100%) was done with water off. Water off results in higher airflows. Remaining tests completed with water off.

SUMMARY	
Total Flow (CFM)	**160,681**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**17.85**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**40.17**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	9B
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Recirc
Fan Speed	100%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu



Logger Start	10/9/2019 8:30	3
Logger End	10/9/2019 8:43	788
Analyse Start	10/9/2019 8:38	437
Analyse End	10/9/2019 8:43	732

		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	53.2	0.214	2.6	0.010	437	732
Thru Cooling Coil	delta PB	150.1	0.603	3.2	0.013	437	732
Thru Fan Bank	delta PC	-361.2	-1.451	3.7	0.015	437	732
Thru Humidicell Deck	delta PD	45.1	0.181	3.2	0.013	437	732
Into Sup Plenum (Short)	delta PE1	31.7	0.127	2.8	0.011	437	732
Into Sup Plenum (Middle)	delta PE2	36.1	0.145	1.8	0.007	437	732
Into Sup Plenum (Long)	delta PE3	48.4	0.194	1.8	0.007	437	732
Sup to Exh Plenum	delta PF	84.4	0.339	0.8	0.003	437	732
Exh Plenum to Return	delta PG	12.7	0.051	1.2	0.005	437	732
Thru Return Damper	delta PH	25.1	0.101	3.2	0.013	437	732
Exh Plenum to Exh Louvers	delta PI	-0.4	-0.001	0.1	0.000	437	732
Thru Exhaust Louvers	delta PJ	-1.8	-0.007	0.6	0.002	437	732

Total Flow (CFM) 160,681.47

Fliow/Ton Potatoes (assume 9000 tons) 17.85

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 10	10/9/2019	9:17 AM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @50%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

0.96	0.97	1.13	0.99	1.05	0.89	1.05	0.83	4
0.94	0.91	1.03	0.88	1.03	0.87	0.88	0.70	3
1.01	0.93	1.01	1.15	1.01	1.10	1.03	1.03	2
0.86	0.81	1.00	0.81	0.84	0.86	0.79	0.69	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

3.84	7.76	9.04	6.93	7.35	7.12	8.40	3.32	4
7.31	14.15	16.02	11.98	14.02	13.53	13.69	5.44	3
7.85	14.46	15.71	15.65	13.74	17.11	16.02	8.01	2
3.44	6.48	8.00	5.67	5.88	6.88	6.32	2.76	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	3.96	8.00	9.32	7.15	7.58	7.34	8.66	3.42	4
Area Weighted Average (m/s)	0.99	7.54	14.60	16.52	12.35	14.46	13.95	14.11	5.61	3
		8.10	14.92	16.20	16.14	14.18	17.64	16.52	8.26	2
		3.55	6.68	8.25	5.85	6.06	7.10	6.52	2.85	1
		A	B	C	D	E	F	G	H	

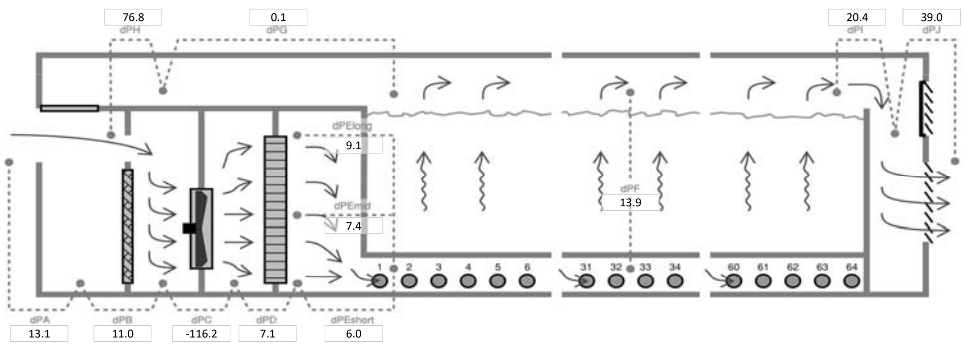
SUMMARY	
Total Flow (CFM)	**61,677**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**6.85**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**15.42**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	10
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Fresh
Fan Speed	50%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 8:50	3
Logger End	10/9/2019 9:25	2092
Analyse Start	10/9/2019 9:17	1582
Analyse End	10/9/2019 9:24	1996



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	13.1	0.053	1.1	0.004	1582	1996
Thru Cooling Coil	delta PB	11.0	0.044	13.7	0.055	1582	1996
Thru Fan Bank	delta PC	-116.2	-0.467	14.0	0.056	1582	1996
Thru Humidicell Deck	delta PD	7.1	0.029	1.5	0.006	1582	1996
Into Sup Plenum (Short)	delta PE1	6.0	0.024	0.9	0.004	1582	1996
Into Sup Plenum (Middle)	delta PE2	7.4	0.030	0.8	0.003	1582	1996
Into Sup Plenum (Long)	delta PE3	9.1	0.037	1.6	0.007	1582	1996
Sup to Exh Plenum	delta PF	13.9	0.056	0.5	0.002	1582	1996
Exh Plenum to Return	delta PG	0.1	0.000	0.3	0.001	1582	1996
Thru Return Damper	delta PH	76.8	0.308	1.4	0.005	1582	1996
Exh Plenum to Exh Louvers	delta PI	20.4	0.082	0.9	0.003	1582	1996
Thru Exhaust Louvers	delta PJ	39.0	0.157	1.0	0.004	1582	1996

Total Flow (CFM)	61,677.39
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	6.85

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 11	10/9/2019	9:40 AM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 100%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

2.69	2.47	2.73	2.30	2.50	2.04	2.40	1.82	4
2.24	2.04	2.48	1.90	2.46	1.90	1.84	1.73	3
2.40	2.23	2.30	2.86	2.35	2.50	2.31	2.40	2
2.37	2.07	2.13	2.12	1.93	1.99	1.83	1.67	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

10.76	19.76	21.84	16.10	17.50	16.32	19.20	7.28	4
17.42	31.73	38.57	25.86	33.48	29.55	28.62	13.45	3
18.66	34.68	35.77	38.92	31.98	38.88	35.93	18.66	2
9.48	16.56	17.04	14.84	13.51	15.92	14.64	6.68	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	11.10	20.38	22.52	16.60	18.05	16.83	19.80	7.51	4
Area Weighted Average (m/s)	2.30	17.96	32.72	39.78	26.67	34.53	30.48	29.51	13.87	3
		19.25	35.77	36.89	40.14	32.98	40.10	37.05	19.25	2
		9.78	17.08	17.57	15.31	13.93	16.42	15.10	6.89	1
		A	B	C	D	E	F	G	H	

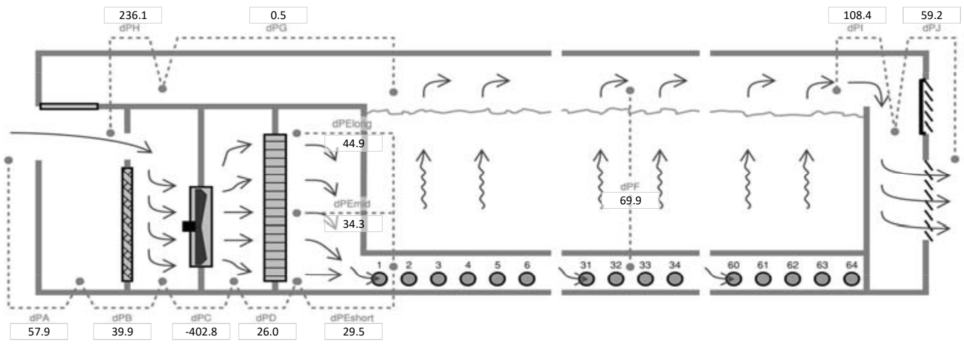
SUMMARY	
Total Flow (CFM)	**144,022**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**16.00**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**36.01**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	11
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Fresh
Fan Speed	100%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 9:43	3
Logger End	10/9/2019 10:09	1588
Analyse Start	10/9/2019 9:50	414
Analyse End	10/9/2019 10:05	1300



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	57.9	0.232	1.9	0.008	414	1300
Thru Cooling Coil	delta PB	39.9	0.160	1.7	0.007	414	1300
Thru Fan Bank	delta PC	-402.8	-1.618	4.3	0.017	414	1300
Thru Humidicell Deck	delta PD	26.0	0.104	4.3	0.017	414	1300
Into Sup Plenum (Short)	delta PE1	29.5	0.118	6.3	0.025	414	2092
Into Sup Plenum (Middle)	delta PE2	34.3	0.138	3.6	0.015	414	1300
Into Sup Plenum (Long)	delta PE3	44.9	0.180	3.7	0.015	414	1300
Sup to Exh Plenum	delta PF	69.9	0.281	0.8	0.003	414	1300
Exh Plenum to Return	delta PG	0.5	0.002	0.5	0.002	414	1300
Thru Return Damper	delta PH	236.1	0.948	2.4	0.010	414	1300
Exh Plenum to Exh Louvers	delta PI	108.4	0.435	1.5	0.006	414	1300
Thru Exhaust Louvers	delta PJ	59.2	0.238	9.1	0.037	414	2092

Total Flow (CFM)	144,021.59
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	16.00

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 12	10/9/2019	11:20 AM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 50%, Extra Louvers open

AREA (sq.ft.)

			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

1.09	1.08	1.24	1.12	1.08	0.97	1.12	0.99	4
1.06	1.00	1.09	1.03	1.08	0.95	0.94	0.91	3
1.14	1.09	1.05	1.25	1.08	1.06	0.86	1.11	2
1.02	1.07	0.93	0.93	0.87	0.86	0.80	0.79	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

4.36	8.64	9.92	7.84	7.56	7.76	8.96	3.96	4
8.24	15.55	16.95	14.02	14.70	14.77	14.62	7.08	3
8.86	16.95	16.33	17.01	14.70	16.49	13.37	8.63	2
4.08	8.56	7.44	6.51	6.09	6.88	6.40	3.16	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	4.49	8.90	10.22	8.08	7.79	8.00	9.23	4.08	4
Area Weighted Average (m/s)	1.06	8.49	16.02	17.47	14.44	15.14	15.22	15.06	7.29	3
		9.13	17.47	16.83	17.53	15.14	16.99	13.78	8.89	2
		4.20	8.82	7.67	6.71	6.27	7.09	6.59	3.26	1
		A	B	C	D	E	F	G	H	

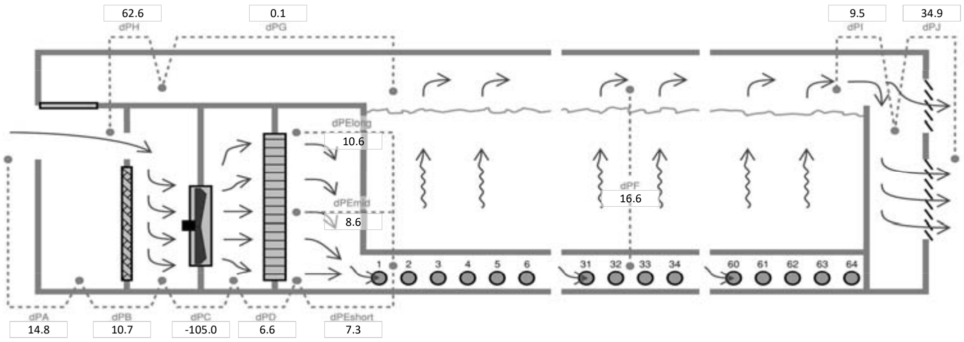
SUMMARY	
Total Flow (CFM)	**66,183**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**7.35**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**16.55**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	12
Bay No.	1
Stored	Potato
No. Fans	4
Flow Mode	Fresh
Fan Speed	50%
Extra Louvers	Open

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 11:21	3
Logger End	10/9/2019 11:44	1393
Analyse Start	10/9/2019 11:24	170
Analyse End	10/9/2019 11:44	1353



		Average (Pa)	Average (in H2O)	Std Dev (Pa)	Std Dev (in H2O)	Limits Start	Limits End
Through Fresh Air Louvers	delta PA	14.8	0.059	1.0	0.004	170	1353
Thru Cooling Coil	delta PB	10.7	0.043	0.8	0.003	170	1353
Thru Fan Bank	delta PC	-105.0	-0.422	1.7	0.007	170	1353
Thru Humidicell Deck	delta PD	6.6	0.026	1.5	0.006	170	1353
Into Sup Plenum (Short)	delta PE1	7.3	0.029	1.0	0.004	170	1353
Into Sup Plenum (Middle)	delta PE2	8.6	0.035	1.3	0.005	170	1353
Into Sup Plenum (Long)	delta PE3	10.6	0.042	1.1	0.004	170	1353
Sup to Exh Plenum	delta PF	16.6	0.067	0.4	0.002	170	1353
Exh Plenum to Return	delta PG	0.1	0.000	0.2	0.001	170	1353
Thru Return Damper	delta PH	62.6	0.252	1.4	0.006	170	1353
Exh Plenum to Exh Louvers	delta PI	9.5	0.038	0.4	0.002	170	1353
Thru Exhaust Louvers	delta PJ	34.9	0.140	0.8	0.003	170	1353

Total Flow (CFM)	66,182.65
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	7.35

GP1, Bay 1, Full of Potatoes	ID	Date	Time	Staff present	Condition Description
	Test 13	10/9/2019	11:50 AM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 100%, Extra Louvers open

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	
			2	4	4	3.5	3.5	4	4	2	ft
Total Height (ft)	11.78	2	4	8	8	7	7	8	8	4	4
Total Width (ft)	27.00	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	3
Total Area (sf)	317.95	3.89	7.8	15.6	15.6	13.6	13.6	15.6	15.6	7.8	2
		2	4.0	8.0	8.0	7.0	7.0	8.0	8.0	4.0	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

3.01	2.86	3.11	2.86	2.58	2.43	2.37	2.18	4
2.76	2.41	2.72	2.50	2.56	2.33	2.15	2.13	3
2.70	2.61	2.56	3.20	2.68	2.64	2.42	2.59	2
2.56	2.47	2.22	2.23	2.13	2.00	1.90	2.00	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

12.04	22.88	24.88	20.02	18.06	19.44	18.96	8.72	4
21.46	37.48	42.30	34.02	34.84	36.24	33.44	16.56	3
21.00	40.59	39.81	43.55	36.47	41.06	37.64	20.14	2
10.24	19.76	17.76	15.61	14.91	16.00	15.20	8.00	1
A	B	C	D	E	F	G	H	

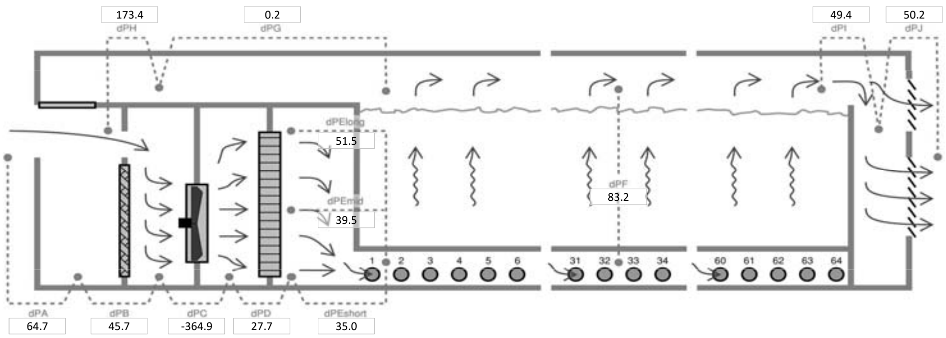
PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	12.41	23.57	25.63	20.63	18.61	20.03	19.54	8.98	4
Area Weighted Average (m/s)	2.59	22.11	38.62	43.58	35.05	35.89	37.34	34.45	17.07	3
		21.63	41.82	41.02	44.87	37.58	42.30	38.78	20.75	2
		10.55	20.36	18.30	16.08	15.36	16.49	15.66	8.24	1
		A	B	C	D	E	F	G	H	

SUMMARY	
Total Flow (CFM)	**162,026**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**18.00**
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	**40.51**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	13	
Bay No.	1	
Stored	Potato	
No. Fans	4	
Flow Mode	Fresh	
Fan Speed	100%	
Extra Louvers	Open	
Staff	C. Schumacher M. Rumeo D. Stanton X. (Ray) Lu	
Logger Start	10/9/2019 12:01	3
Logger End	10/9/2019 12:26	1491
Analyse Start	10/9/2019 12:05	228
Analyse End	10/9/2019 12:20	1114



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	64.7	0.260	2.3	0.009	228	1114
Thru Cooling Coil	delta PB	45.7	0.184	2.5	0.010	228	1114
Thru Fan Bank	delta PC	-364.9	-1.465	4.5	0.018	228	1114
Thru Humidicell Deck	delta PD	27.7	0.111	4.2	0.017	228	1114
Into Sup Plenum (Short)	delta PE1	35.0	0.141	3.8	0.015	228	1114
Into Sup Plenum (Middle)	delta PE2	39.5	0.158	3.2	0.013	228	1114
Into Sup Plenum (Long)	delta PE3	51.5	0.207	3.3	0.013	228	1114
Sup to Exh Plenum	delta PF	83.2	0.334	0.9	0.004	228	1114
Exh Plenum to Return	delta PG	0.2	0.001	0.3	0.001	228	1114
Thru Return Damper	delta PH	173.4	0.696	2.9	0.011	228	1114
Exh Plenum to Exh Louvers	delta PI	49.4	0.198	0.9	0.004	228	1114
Thru Exhaust Louvers	delta PJ	50.2	0.202	1.0	0.004	228	1114

Total Flow (CFM)	162,026.18
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	18.00

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 14	10/9/2019	5:30 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Recirculation @ 100%, Extra Louvers masked

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	ft
			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
1.50	1.39	1.54	1.50	1.46	1.54	1.21	1.26	4
1.44	1.33	1.37	1.46	1.45	1.24	1.19	1.25	3
1.46	1.58	1.55	1.46	1.35	1.39	0.98	1.22	2
1.53	1.57	1.29	1.44	1.33	1.08	0.96	1.08	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
6.00	11.12	12.32	12.00	11.68	12.32	9.68	5.04	4
11.28	20.84	21.46	22.87	22.72	19.43	18.64	9.79	3
11.44	24.75	24.28	22.87	21.15	21.78	15.35	9.56	2
6.12	12.56	10.32	11.52	10.64	8.64	7.68	4.32	1

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor 1.03
Area Weighted Average (m/s) 1.40

A	B	C	D	E	F	G	H	
6.17	11.44	12.67	12.34	12.01	12.67	9.96	5.18	4
11.60	21.43	22.08	23.53	23.37	19.98	19.18	10.07	3
11.76	25.46	24.98	23.53	21.76	22.40	15.79	9.83	2
6.30	12.92	10.62	11.85	10.94	8.89	7.90	4.44	1

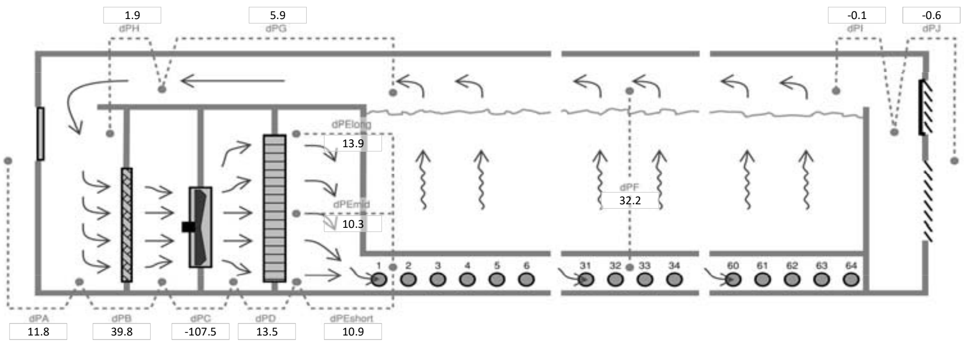
SUMMARY	
Total Flow (CFM)	**91,132**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**10.13**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**17.53**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	14
Bay No.	5
Stored	Onion
No. Fans	5
Flow Mode	Recirc
Fan Speed	50%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 17:28	3
Logger End	10/9/2019 17:48	1207
Analyse Start	10/9/2019 17:38	559
Analyse End	10/9/2019 17:47	1091



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	11.8	0.047	1.7	0.007	559	1091
Thru Cooling Coil	delta PB	39.8	0.160	1.3	0.005	559	1091
Thru Fan Bank	delta PC	-107.5	-0.432	1.6	0.006	559	1091
Thru Humidicell Deck	delta PD	13.5	0.054	1.0	0.004	559	1091
Into Sup Plenum (Short)	delta PE1	10.9	0.044	1.2	0.005	559	1091
Into Sup Plenum (Middle)	delta PE2	10.3	0.041	1.2	0.005	559	1091
Into Sup Plenum (Long)	delta PE3	13.9	0.056	2.2	0.009	559	1091
Sup to Exh Plenum	delta PF	32.2	0.129	0.3	0.001	559	1091
Exh Plenum to Return	delta PG	5.9	0.024	0.4	0.002	559	1091
Thru Return Damper	delta PH	1.9	0.008	0.7	0.003	559	1091
Exh Plenum to Exh Louvers	delta PI	-0.1	0.000	0.1	0.000	559	1091
Thru Exhaust Louvers	delta PJ	-0.6	-0.002	0.4	0.001	559	1091

Total Flow (CFM)	91,131.65
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	22.78

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 15	10/9/2019	5:50 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Recirculation @ 100%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	2.06
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

3.39	2.95	3.47	3.19	3.68	3.75	2.72	2.76	4
3.26	3.05	3.11	3.34	3.54	3.05	2.78	2.76	3
3.19	3.49	3.59	3.39	3.01	3.25	2.05	2.67	2
3.15	3.24	2.94	2.75	2.82	2.04	2.03	2.06	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

13.56	23.60	27.76	25.52	29.44	30.00	21.76	11.04	4
25.54	47.78	48.72	52.33	55.46	47.78	43.55	21.62	3
24.99	54.68	56.24	53.11	47.16	50.92	32.12	20.92	2
12.60	25.92	23.52	22.00	22.56	16.32	16.24	8.24	1
A	B	C	D	E	F	G	H	

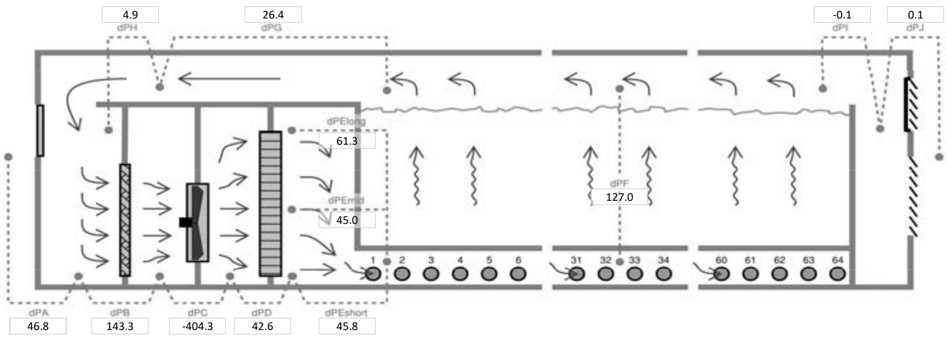
PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	13.95	24.28	28.56	26.25	30.28	30.86	22.38	11.36	4
Area Weighted Average (m/s)	3.14	26.27	49.15	50.12	53.83	57.05	49.15	44.80	22.24	3
		25.70	56.24	57.85	54.63	48.51	52.37	33.04	21.51	2
		12.96	26.66	24.19	22.63	23.21	16.79	16.71	8.48	1
		A	B	C	D	E	F	G	H	

SUMMARY	
Total Flow (CFM)	**205,066**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**22.79**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**39.44**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	15	
Bay No.	5	
Stored	Onion	
No. Fans	5	
Flow Mode	Recirc	
Fan Speed	100%	
Extra Louvers	Masked	
Staff	C. Schumacher M. Rumeo D. Stanton X. (Ray) Lu	
Logger Start	10/9/2019 17:49	3
Logger End	10/9/2019 18:15	1527
Analyse Start	10/9/2019 17:50	34
Analyse End	10/9/2019 18:10	1216



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	46.8	0.188	5.1	0.020	34	1216
Thru Cooling Coil	delta PB	143.3	0.576	6.4	0.026	34	1216
Thru Fan Bank	delta PC	-404.3	-1.624	14.4	0.058	34	1216
Thru Humidicell Deck	delta PD	42.6	0.171	4.8	0.019	34	1216
Into Sup Plenum (Short)	delta PE1	45.8	0.184	7.7	0.031	34	1216
Into Sup Plenum (Middle)	delta PE2	45.0	0.181	13.0	0.052	34	1216
Into Sup Plenum (Long)	delta PE3	61.3	0.246	12.2	0.049	34	1216
Sup to Exh Plenum	delta PF	127.0	0.510	5.3	0.021	34	1216
Exh Plenum to Return	delta PG	26.4	0.106	1.7	0.007	34	1216
Thru Return Damper	delta PH	4.9	0.020	2.5	0.010	34	1216
Exh Plenum to Exh Louvers	delta PI	-0.1	-0.001	0.4	0.002	34	1216
Thru Exhaust Louvers	delta PJ	0.1	0.000	4.9	0.020	34	1216

Total Flow (CFM)	205,065.69
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	51.27

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 16	10/9/2019	3:30 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 50%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	2.06
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

1.43	1.15	1.33	1.19	1.28	1.29	1.01	1.07	4
1.32	1.22	1.14	1.21	1.26	1.18	1.00	1.15	3
1.36	1.30	1.33	1.19	1.14	1.15	0.82	1.05	2
1.20	1.29	1.13	1.17	1.09	0.92	0.71	0.89	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

5.72	9.20	10.64	9.52	10.24	10.32	8.08	4.28	4
10.34	19.11	17.86	18.96	19.74	18.49	15.67	9.01	3
10.65	20.37	20.84	18.64	17.86	18.02	12.85	8.23	2
4.80	10.32	9.04	9.36	8.72	7.36	5.68	3.56	1
A	B	C	D	E	F	G	H	

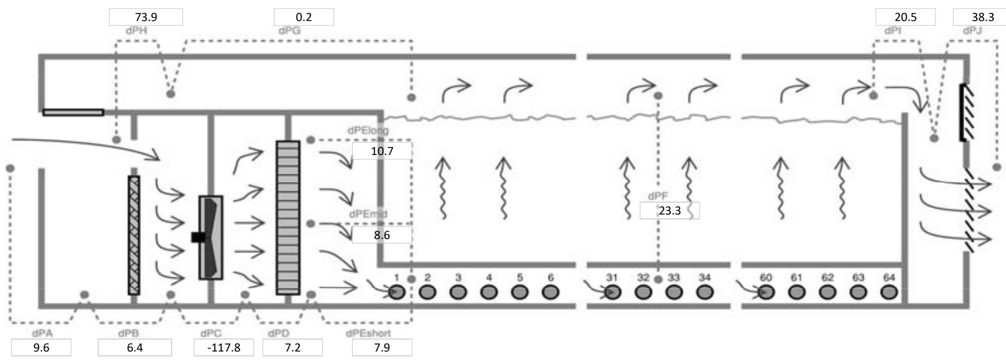
PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	5.89	9.47	10.96	9.80	10.54	10.63	8.32	4.41	4
Area Weighted Average (m/s)	1.19	10.65	19.68	18.39	19.52	20.33	19.03	16.13	9.28	3
		10.97	20.97	21.45	19.20	18.39	18.55	13.23	8.47	2
		4.94	10.63	9.31	9.64	8.98	7.58	5.85	3.67	1
		A	B	C	D	E	F	G	H	

SUMMARY	
Total Flow (CFM)	**77,703**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**8.63**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**14.94**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	16
Bay No.	5
Stored	Onion
No. Fans	5
Flow Mode	Fresh
Fan Speed	50%
Extra Louvers	Masked
Staff	C. Schumacher M. Rumeo D. Stanton X. (Ray) Lu
Logger Start	10/9/2019 15:40	3
Logger End	10/9/2019 16:46	3874
Analyse Start	10/9/2019 15:41	31
Analyse End	10/9/2019 16:31	2985



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	9.6	0.038	1.3	0.005	31	2985
Thru Cooling Coil	delta PB	6.4	0.026	0.9	0.004	31	1747
Thru Fan Bank	delta PC	-117.8	-0.473	14.0	0.056	31	1747
Thru Humidicell Deck	delta PD	7.2	0.029	1.6	0.007	31	1747
Into Sup Plenum (Short)	delta PE1	7.9	0.032	3.6	0.014	31	1747
Into Sup Plenum (Middle)	delta PE2	8.6	0.034	1.9	0.008	31	1747
Into Sup Plenum (Long)	delta PE3	10.7	0.043	2.0	0.008	31	1747
Sup to Exh Plenum	delta PF	23.3	0.093	3.6	0.014	31	1747
Exh Plenum to Return	delta PG	0.2	0.001	1.2	0.005	31	1747
Thru Return Damper	delta PH	73.9	0.297	9.0	0.036	31	1747
Exh Plenum to Exh Louvers	delta PI	20.5	0.082	2.8	0.011	31	1747
Thru Exhaust Louvers	delta PJ	38.3	0.154	5.1	0.020	31	1747

Total Flow (CFM)	77,702.64
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	19.43

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 17	10/9/2019	4:47 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 100%, Extra Louvers masked

AREA (sq.ft.)

			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	2.06
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

3.76	2.70	3.28	2.59	3.30	3.01	2.26	2.39	4
3.49	2.69	2.77	3.08	3.24	2.97	2.53	2.60	3
3.56	2.98	3.41	3.34	2.81	2.72	1.84	1.93	2
3.21	2.96	2.62	2.99	2.54	1.85	1.66	1.62	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

15.04	21.60	26.24	20.72	26.40	24.08	18.08	9.56	4
27.34	42.14	43.40	48.25	50.76	46.53	39.64	20.37	3
27.89	46.69	53.42	52.33	44.02	42.61	28.83	15.12	2
12.84	23.68	20.96	23.92	20.32	14.80	13.28	6.48	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	15.47	22.22	26.99	21.31	27.16	24.77	18.60	9.83	4
Area Weighted Average (m/s)	2.88	28.12	43.35	44.64	49.64	52.21	47.86	40.77	20.95	3
		28.69	48.02	54.95	53.83	45.28	43.83	29.65	15.55	2
		13.21	24.36	21.56	24.61	20.90	15.22	13.66	6.67	1
		A	B	C	D	E	F	G	H	

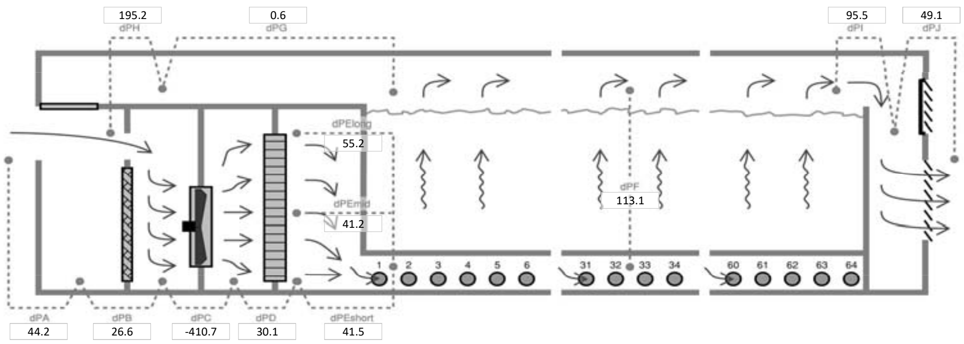
SUMMARY	
Total Flow (CFM)	**187,725**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**20.86**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**36.10**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	17
Bay No.	5
Stored	Onion
No. Fans	5
Flow Mode	Fresh
Fan Speed	100%
Extra Louvers	Masked

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 17:13	3
Logger End	10/9/2019 17:18	306
Analyse Start	10/9/2019 17:14	13
Analyse End	10/9/2019 17:17	191



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	44.2	0.178	1.4	0.006	13	191
Thru Cooling Coil	delta PB	26.6	0.107	1.9	0.008	13	191
Thru Fan Bank	delta PC	-410.7	-1.650	7.3	0.029	13	191
Thru Humidicell Deck	delta PD	30.1	0.121	4.1	0.016	13	191
Into Sup Plenum (Short)	delta PE1	41.5	0.167	3.0	0.012	13	191
Into Sup Plenum (Middle)	delta PE2	41.2	0.165	3.1	0.012	13	191
Into Sup Plenum (Long)	delta PE3	55.2	0.222	2.6	0.011	13	191
Sup to Exh Plenum	delta PF	113.1	0.454	1.2	0.005	13	191
Exh Plenum to Return	delta PG	0.6	0.002	0.6	0.003	13	191
Thru Return Damper	delta PH	195.2	0.784	5.3	0.021	13	191
Exh Plenum to Exh Louvers	delta PI	95.5	0.384	3.6	0.014	13	191
Thru Exhaust Louvers	delta PJ	49.1	0.197	1.5	0.006	13	191

Total Flow (CFM)	187,725.02
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	46.93

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 18	10/8/2019	7:05 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 50%, Extra Louvers open

AREA (sq.ft.)

			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	2.06
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

1.48	1.25	1.28	1.20	1.41	1.20	1.10	1.37	4
1.45	1.26	1.19	1.42	1.40	1.23	1.26	1.38	3
1.45	1.26	1.36	1.48	1.24	1.16	0.99	1.11	2
1.48	1.33	1.15	1.29	1.22	0.99	0.81	0.94	1
A	B	C	D	E	F	G	H	

AREA-WEIGHTED VELOCITY (m/s*ft2)

5.92	10.00	10.24	9.60	11.28	9.60	8.80	5.48	4
11.36	19.74	18.64	22.25	21.93	19.27	19.74	10.81	3
11.36	19.74	21.31	23.19	19.43	18.17	15.51	8.70	2
5.92	10.64	9.20	10.32	9.76	7.92	6.48	3.76	1
A	B	C	D	E	F	G	H	

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

Velocity Correction Factor	1.03	6.09	10.28	10.53	9.87	11.60	9.87	9.05	5.63	4
Area Weighted Average (m/s)	1.29	11.68	20.29	19.16	22.87	22.55	19.81	20.29	11.11	3
		11.68	20.29	21.90	23.83	19.97	18.68	15.94	8.94	2
		6.09	10.94	9.46	10.61	10.03	8.14	6.66	3.87	1
		A	B	C	D	E	F	G	H	

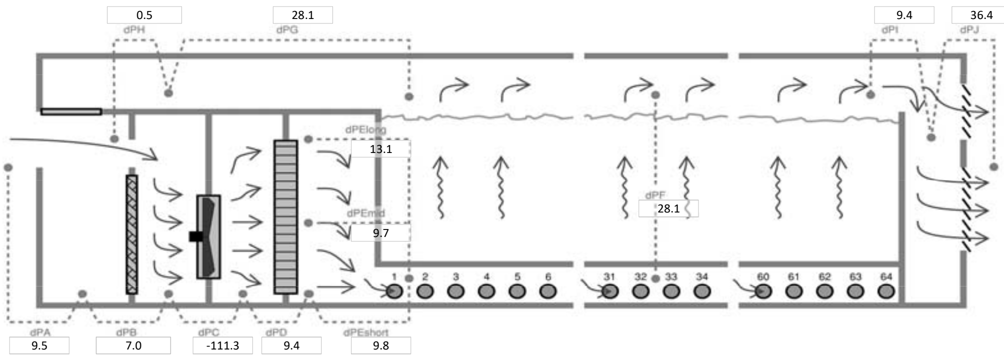
SUMMARY	
Total Flow (CFM)	**84,170**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**9.35**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**16.19**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	18
Bay No.	5
Stored	Onion
No. Fans	5
Flow Mode	Fresh
Fan Speed	50%
Extra Louvers	Open

Staff: C. Schumacher, M. Rumeo, D. Stanton, X. (Ray) Lu

Logger Start	10/9/2019 19:02	3
Logger End	10/9/2019 19:24	1319
Analyse Start	10/9/2019 19:05	178
Analyse End	10/9/2019 19:17	887



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	9.5	0.038	0.6	0.002	178	887
Thru Cooling Coil	delta PB	7.0	0.028	0.6	0.002	178	887
Thru Fan Bank	delta PC	-111.3	-0.447	2.0	0.008	178	887
Thru Humidicell Deck	delta PD	9.4	0.038	1.4	0.006	178	887
Into Sup Plenum (Short)	delta PE1	9.8	0.039	1.4	0.006	178	887
Into Sup Plenum (Middle)	delta PE2	9.7	0.039	1.3	0.005	178	887
Into Sup Plenum (Long)	delta PE3	13.1	0.053	1.3	0.005	178	887
Sup to Exh Plenum	delta PF	28.1	0.113	0.5	0.002	178	887
Exh Plenum to Return	delta PG	28.1	0.113	0.5	0.002	178	887
Thru Return Damper	delta PH	0.5	0.002	0.3	0.001	178	887
Exh Plenum to Exh Louvers	delta PI	9.4	0.038	0.2	0.001	178	887
Thru Exhaust Louvers	delta PJ	36.4	0.146	0.4	0.002	178	887

Total Flow (CFM)	84,169.66
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	21.04

GP2, Bay 5, Full of Onions	ID	Date	Time	Staff present	Condition Description
	Test 19	10/9/2019	7:30 PM	C. Schumacher, M. Rumeo, D. Stanton, X. Lu	Fresh air @ 100%, Extra Louvers open

AREA (sq.ft.)

			A	B	C	D	E	F	G	H	
			2	4	4	4	4	4	4	2	ft
Total Height (ft)	11.83	2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	4
Total Width (ft)	28.00	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	3
Total Area (sf)	331.33	3.92	7.83	15.67	15.67	15.67	15.67	15.67	15.67	7.83	2
		2	4.00	8.00	8.00	8.00	8.00	8.00	8.00	4.00	1
		ft	A	B	C	D	E	F	G	H	

VELOCITY (m/s)

A	B	C	D	E	F	G	H	
3.99	2.92	3.33	3.04	3.09	3.34	2.44	2.41	4
3.46	3.06	2.92	3.49	3.37	3.19	2.45	2.57	3
3.37	3.05	3.52	3.24	2.85	2.74	2.07	2.35	2
3.34	3.14	2.92	3.12	2.86	1.97	1.87	2.06	1

AREA-WEIGHTED VELOCITY (m/s*ft2)

A	B	C	D	E	F	G	H	
15.96	23.36	26.64	24.32	24.72	26.72	19.52	9.64	4
27.10	47.94	45.75	54.68	52.80	49.98	38.38	20.13	3
26.40	47.78	55.15	50.76	44.65	42.93	32.43	18.41	2
13.36	25.12	23.36	24.96	22.88	15.76	14.96	8.24	1

PRESSURE-CORRECTED AREA-WEIGHTED VELOCITY (m/s*ft2)

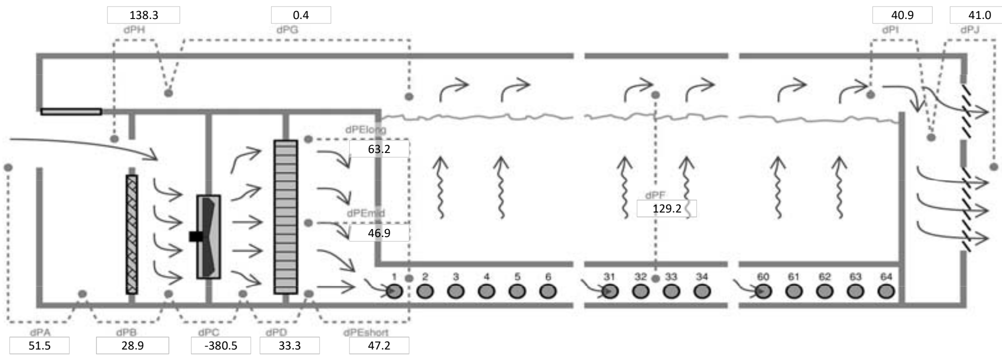
Velocity Correction Factor 1.03
Area Weighted Average (m/s) 3.02

A	B	C	D	E	F	G	H	
16.40	24.00	27.37	24.98	25.39	27.45	20.05	9.90	4
27.84	49.25	46.99	56.17	54.24	51.34	39.43	20.68	3
27.12	49.09	56.65	52.14	45.87	44.10	33.31	18.91	2
13.72	25.81	24.00	25.64	23.50	16.19	15.37	8.46	1

SUMMARY	
Total Flow (CFM)	**197,070**
Flow/Ton Potatoes (assume 9000 tons) (CFM/Ton)	**21.90**
Flow/Ton Onions (assume 5200 tons) (CFM/Ton)	**37.90**

Terra Gold Othello Storage - Airflow Investigation
RDH Building Science Inc. 10/9/2019

Test No.	19	
Bay No.	5	
Stored	Onion	
No. Fans	5	
Flow Mode	Fresh	
Fan Speed	100%	
Extra Louvers	Open	
Staff	C. Schumacher	
	M. Rumeo	
	D. Stanton	
	X. (Ray) Lu	
Logger Start	10/9/2019 19:26	3
Logger End	10/9/2019 19:49	1372
Analyse Start	10/9/2019 19:29	137
Analyse End	10/9/2019 19:47	1201



		Average		Std Dev		Limits	
		(Pa)	(in H2O)	(Pa)	(in H2O)	Start	End
Through Fresh Air Louvers	delta PA	51.5	0.207	1.2	0.005	137	1201
Thru Cooling Coil	delta PB	28.9	0.116	2.3	0.009	137	1201
Thru Fan Bank	delta PC	-380.5	-1.528	6.3	0.025	137	1201
Thru Humidicell Deck	delta PD	33.3	0.134	4.0	0.016	137	1201
Into Sup Plenum (Short)	delta PE1	47.2	0.189	5.2	0.021	137	1201
Into Sup Plenum (Middle)	delta PE2	46.9	0.188	5.0	0.020	137	1201
Into Sup Plenum (Long)	delta PE3	63.2	0.254	4.4	0.018	138	1202
Sup to Exh Plenum	delta PF	129.2	0.519	1.0	0.004	137	1201
Exh Plenum to Return	delta PG	0.4	0.002	0.3	0.001	137	1201
Thru Return Damper	delta PH	138.3	0.555	4.3	0.017	137	1201
Exh Plenum to Exh Louvers	delta PI	40.9	0.164	0.5	0.002	137	1201
Thru Exhaust Louvers	delta PJ	41.0	0.164	0.9	0.004	137	1201

Total Flow (CFM)	197,070.19
Flow/Ton Onions (assume 4000 tons) (CFM/Ton)	49.27